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USSR REPORT

SPACE BIOLOGY AND AEROSPACE MEDICINE

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FLUID-ELECTROLYTE HOMEOSTASIS AND WEIGHTLESSNESS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 5, 1980 pp 3-10

[Article by O. G. Gazenko, A. I. Grigor'yev and Yu. V. Natochin, submitted 29 Oct 79]

[Text] Stable volume, osmotic concentration and ionic composition of internal fluids are a mandatory prerequisite for man to be in a good condition and highly efficient. Physiological systems regulate the concentration of each electrolyte in blood (and other endogenous fluids), the balance between intake and output thereof and, consequently, total salt content of the body. At present, sufficient material has been accumulated concerning the effect of weightlessness on fluid-electrolyte metabolism, so that it is necessary to sum up some of the findings and discuss the most pressing problems.

Weightlessness was found to be the most serious factor among those to which cosmonauts are exposed during flights. In the case of short and moderate duration of flights, it was possible to overcome this obstacle to a significant extent [1-4]. During missions lasting up to 8 days, the main disturbances were referable to the vestibular system and hemodynamic changes; in flights last 1 to 2-3 months, this applied to changes referable to the musculoskeletal system due to hypodynamia and absence of gravity. Already the examination of the first cosmonauts revealed a significant weight loss and substantial changes in balance of fluid and a number of electrolytes. Although homeostatic mechanisms did counteract the changes in composition of endogenous fluids, and concentration of electrolytes in blood changed minimally, this was attributable to rather intensive function of the systems of regulation and excretory organs, primarily the kidneys. A tendency toward hypokalemia and hypercalcemia was the most frequent manifestation of changes in electrolyte metabolism after long-term flights. In a number of cases, hypernatremia and increased osmolarity of blood were also noted. All these changes reverted to normal several days or weeks after the cosmonauts returned to earth. A negative balance of potassium, calcium, phosphorus and a number of other electrolytes was demonstrated.

The purpose of this survey was to discuss the causes, mechanisms and significance of disturbances in electrolyte metabolism, to determine whether they are primary or secondary, as well as to determine the systems (regulatory or of tissue metabolism), changes in which caused these disturbances. This is of basic importance to development of preventive methods and comprehension of the mechanisms of action of weightlessness on the human body. There is no question of the fact that changes in fluid-electrolyte metabolism play an important role in development of orthostatic instability, diminished physical fitness and endurance of accelerations, change in bioelectrical activity of the myocardium and a number of other disturbances in cosmonauts. They differ at different phases of a flight, and they depend largely on its duration.

Regulation of Volume and Osmosis

By regulating the concentration of sodium and chlorine in extracellular fluids and balance thereof in the body, physiological systems provide for stability of two of the most important homeostatic parameters: volume of fluid (volume regulation) and concentration of osmotically active substances in them (osmoregulation). The change from earth's gravity to weightlessness results primarily in redistribution of blood in the body. The absence of gravity causes blood to shift from the lower limbs to the region of the thoracic vessels, plethora of the latter and distention of the atria [5, 6], which leads to reflex increase in renal excretion of fluid. Since these acute reactions occur under isoosmic conditions (i.e., without change in concentration of osmotically active substances and ion composition of blood), they probably are in the nature of a volume-regulating reflex [7], the Henry-Gauer reflex. A negative fluid and electrolyte balance is observed in weightlessness [8, 9], when it is simulated by immersion [10-12], during hypokinesia by means of bed rest, particularly in antiorthostatic [head tilted down] position [13, 14]. The cosmonauts' physiological reactions at the first stage of adaptation to weightlessness are not limited to increased renal excretion of fluid. They are manifested by diminished thirst and fluid intake, as well as diminished desire for salt. The rush of blood to the thoracic region and head is manifested by edema of the face, sensation of heaviness of the head, etc. [15-17]. No doubt, adaptation of the system of regulation of volume is adequate to the new conditions, and it is instrumental in improving the well-being and condition of cosmonauts. It is of substantial importance to settle the question of what are the most beneficial rate and individual distinctions of the adaptation process when becoming exposed to weightlessness. Adaptation can be speeded up with pharmacological agents, which increase renal excretion of fluid and sodium salts, for the purpose of faster reduction of volume of extracellular fluid.

The change in fluid metabolism persists for some time after completion of a flight. This is manifested by the fact that, in spite of increased fluid intake, there is a decrease in diuresis [13, 18, 19]. Use of a standard fluid load revealed that there was diminished excretion of fluid [13, 20, 21]. Since blood osmolarity was normal in the cosmonauts, fluid

retention was apparently attributable to a diminished volume of fluid in the body, due to weightlessness [20, 22-24]. After the flight, there was a decrease in maximum diuresis, as well as excretion of osmotically free fluid, with virtually normal level of glomerular filtration [25]. This was apparently indicative of the fact that, in spite of the fluid load, the cosmonauts retained a significant level of antidiuretic hormone (ADH) in their blood. Under ordinary conditions, intake of such a fluid load is associated with virtually complete arrest of ADH secretion. The continuing secretion of ADH could be attributable to inadequate volume regulation, since ADH is secreted not only in response to an increase in osmotic concentration of blood, but to a decrease in volume thereof, in particular when there is diminished delivery of blood to the atria [26]. When the volume of extracellular fluid was diminished after the cosmonauts returned to earth, or if it was inadequate to the new conditions due to deconditioning of the vascular bed under the influence of gravity, this led to secretion of superfluous ADH, and this was demonstrated with the water load test. Intensified ADH excretion by the kidneys after the flight was demonstrated by direct measurement of its activity in urine [2, 9].

These data made it necessary to take direct readings of volumes of fluid phases of the body. The results of such studies were quite contradictory. Blood volume decreased by 13 and 6% in astronauts who flew aboard the Gemini-4 and Gemini-5 spacecraft, respectively, after a 2-week mission [22]; no decrease in blood volume and extracellular fluid was noted in astronauts who flew aboard Gemini-7 and the flight engineer aboard Soyuz-14 [27], whereas there was a decrease in volume of extracellular fluid in the commander of Soyuz-14. Similar studies conducted on the Apollo and Skylab program revealed that the volume of extracellular fluid was diminished in a number of astronauts by the time they returned to earth; it did not differ from base values in others, whereas the decrease in overall volume of fluid in the body was the same (an average of about 2.5%).

Thus, the decrease in total fluid content of the body in the case of short-term flights was attributable to loss primarily of extracellular fluid. With longer exposure to weightlessness, the volume of extracellular fluid was probably gradually restored in some cosmonauts, but there was a decrease in overall mass of intracellular fluid. Evidently, this was attributable to atrophic processes in some muscle groups that were not sufficiently exercised in physical training. The diminished reaction to fluid intake observed in most cosmonauts following flights lasting different periods of time warrants raising the question of possible inadequacy of even normal circulating blood and extracellular fluid volume after returning to earth's gravity. Such an inconsistency could be due to deconditioning of vessels of the lower extremities and retention in them of a larger volume than usual, and, consequently, diminished filling with blood of the central vascular bed. These data are of practical importance: at the final phase of flight, with the transition from weightlessness to earth's gravity (particularly in cases of prolonged exposure to

weightlessness), it is desirable to take in additional amounts of sodium chloride and water in order to increase the volume of extracellular fluid. Use of these elements in the set of preventive measures yielded good results on cosmonauts involved in the second expedition aboard the Salyut-4 orbital station [28].

Processes of osmoregulation and regulation of volume are implemented by the central nervous system, which uses neural conductors and the endocrine system as efferent mechanisms. During the flight aboard the Skylab orbital station, blood aldosterone level was close to the base value; on the day after this flight, its concentration increased by 2.5 times and held at this high level for several days [9]. After the astronauts returned to earth, there was an almost 3-fold increase in blood angiotensin level, although it was only slightly above the base level during the flight. There was a 339% increase in ADH excretion in urine [2]. In view of the physiological significance of these hormones, it may be assumed that intensified secretion thereof upon returning to earth was a manifestation of a compensatory reaction related to the need to augment the volume of intravascular fluid. ADH must be instrumental in fluid retention, aldosterone should aid in retention of sodium, while angiotensin leads to conformity of the vascular bed with the volume of blood and stimulates aldosterone secretion.

Ion Regulation

The electrolyte composition of blood plasma reflects the ion content of most extracellular fluid. However, this parameter does not allow us to assess the balance of ions, since by mobilizing deposited ions it is possible to maintain a normal level thereof for some time with a negative balance, i.e., excessive output in relation to input, etc. We have discussed above the regulation of sodium and chlorine balance; here we shall discuss chiefly questions pertaining to regulation of potassium and calcium metabolism.

In-flight studies of potassium balance were first conduct on the crew of Gemini-7 [29]. In one of the crew members, the potassium deficiency per day constituted a mean of 64.6 meq and in another, 22.9 meq. A negative potassium balance was also demonstrated among the crews of Apollo and Skylab spacecraft. These data were corroborated by a measurement of total potassium content by means of γ-spectrometry [30, 31]. A decrease in amount of metabolizable potassium (^{42}K) was demonstrated in astronauts aboard Apollo-15 even 5 days after the flight [30]. The change in potassium metabolism could have been one of the causes of impaired cardiac function in astronauts aboard Apollo-15. The decrease in total potassium content of the body was significant; for example, total potassium content dropped from 3674 to 3401 meq, i.e., by 7.4%, after a 28-day mission aboard the Skylab station [32].

In all probability, the cause of potassium loss was that atrophic processes develop in muscles in weightlessness and hypodynamia, with

reduction of cellular mass, removal of potassium from cells and excess thereof excreted by the kidneys. Thus, we are probably dealing not only with hypokalemia and diminished intracellular concentration of potassium, but a decrease in cell mass and, consequently, limited space for potassium in the intracellular elements that make it possible to retain it. There are several facts in favor of this hypothesis. The astronauts aboard Apollo-16 and Apollo-17 spacecraft were given a diet with increased potassium content to prevent complications referable to the cardiovascular system. However, in spite of these measures, the crew of Apollo-17 presented a decrease in potassium content of 13.5 meq/kg weight [33]. Addition of potassium to the diet normalizes potassium content of extracellular fluid, as was observed in cosmonauts involved in the second expedition aboard Salyut-4 [34], although it did not eliminate the negative potassium balance. The potassium deficiency, even 6 days after the mission aboard Soyuz-14, constituted 620 meq in the commander and 340 meq in the flight engineer [27].

It may be assumed that the negative potassium balance is not based on the shortage of potassium in the diet, but the impossibility of its retention due to the diminished size of the potassium depot of cells. To check this hypothesis, studies were made with the use of potassium salts (0.75-1.5 meq/kg body weight). It was found that there was faster excretion of the potassium load in the presence of hypokalemia and decrease in total potassium content of the body as a result of prolonged hypokinesia than in the base period [35]. Similar results were obtained on albino rats, which flew aboard the Cosmos-936 biosatellite, when they were given a potassium load. Perhaps, the disturbances referable to potassium metabolism in weightlessness are based on a primary change in tissular metabolism, atrophy and consequent change in total potassium content of cells.

Even when preparing for the first space flights, specialists were concerned with problems that could arise because of impaired calcium metabolism during a space flight [36, 37]. The hypothesis was expounded that serious changes could occur in metabolism of bone tissue due to diminished load [37], which could lead to development of urolithiasis as a result of excretion of excessive amounts of calcium [38]. Use of the densitometry method yielded particularly alarming results: a 2-25% decrease in mineralization of a number of bones was observed in crew members of Gemini and Soyuz spacecraft [39-41]. However, the use of a more accurate method of photon absorption failed to demonstrate such a significant decrease in bone density in astronauts of Apollo-14 and Apollo-16 [42]. A complex study of different bones from autopsy material from the crew of the Salyut-1 orbital station also failed to demonstrate significant deviations from normal [43]. Slight deviations (4.5-7.9%) were demonstrated in some crew members of the Skylab orbital station in tests using the method of photon absorptiometry [44].

A study of mineralization of different bones is not sufficient to assess calcium metabolism. Balance studies demonstrated that there is gradual

increase in excretion of calcium in urine and, in some cases, in feces, starting in the 2d week of the flight [45]. A negative balance of phosphates, magnesium, sulfates and nitrogen was also found [29, 45, 46]. During the missions aboard Skylab, it was established that calcium excretion reaches a maximum after 3-4 weeks, and holds on this level thereafter [46]. Analogous results were obtained in tests using hypokinesia [12-14, 47]. Calcium loss constituted a mean of about 4 g per month [46]. In view of the fact that total calcium content of the human body constitutes about 1.5% of its total weight, this figure does not cause alarm during flights lasting several months.

The increased calcium excretion is attributable to a change in condition of bone tissue in weightlessness; the negative balance of phosphorus, sulfur and magnesium [29, 46] probably reflects catabolism in bone and muscle tissues. In particular, the reduction of perimeter of the thighs is a manifestation of atrophic processes in muscles [15, 48]. Even intensive physical exercise during the flight cannot involve all muscle groups; however, the observed changes are not a deterrent to flights lasting several months, since functional deconditioning of the skeletomuscular system is transient, and it does not impair the mechanical strength of the skeleton.

Thus, the disturbances referable to ion metabolism are attributable primarily to changes in tissues that are the richest in these electrolytes (bone and muscle). The disturbances in electrolyte balance are also related in part to concomitant changes in endocrine status. There was a correlation between increased secretion of aldosterone and intensified excretion of potassium, and this could explain in part the potassium deficiency [2, 31]. However, one must not equate the change in secretion of a hormone with mandatory, adequate change in metabolism of the electrolyte whose balance it regulates. This is due to the presence of back-up mechanisms and a number of factors that adapt the cell to the reaction to the hormone. Analysis of levels in blood of the main regulatory factors for calcium metabolism (parathyroid hormone, thyrocalcitonin, 25-hydroxycalciferol) failed to demonstrate clearcut changes caused by prolonged weightlessness [32]. Activity of a hormone in blood does not determine per se the intensity of the response of an effector organ, since there are modulators of the hormonal effect; at the same time, even minor, but prolonged changes in hormonal activity are sometimes sufficient for occurrence of a substantial change in electrolyte balance.

Functional Capacity of the Kidney and Its Role in Fluid-Electrolyte Homeostasis

Brief and prolonged weightlessness failed to elicit severe changes in renal function. The volume of glomerular filtration and level of tubular reabsorption of various tested substances remained at the base level [20, 25]. The diminished capacity to excrete fluid, which was observed on the first few postflight days [19, 49-51], can be well explained by the state of the

ADH-secreting system. In the presence of dehydration, the "reflux-duplicating" [?] system of the renal medulla functions efficiently, as can be ascertained by the high level of osmotic concentration of urine [25]. However, changes were also demonstrated in function of the concentrating system and its reactions to ADH. As a rule, in man, the lower the diuresis, the higher the osmotic concentration of urine. In cosmonauts, whatever the level of postflight diuresis, the concentration of osmotically active substances in urine and reabsorption of osmotically free water were lower than before the flight [19]. Such a paradoxical reaction was observed against a background of high ADH secretion [51] when, it would seem, there should have been a maximum level of osmotic concentration of urine. Similar findings were also made in studies involving simulation of weightlessness during prolonged hypokinesia in antiorthostatic position [52]. Thus, prolonged weightlessness affects the concentrating capacity of the kidney and its reaction to ADH. A change in ionic homeostasis--hypokalemia and hypercalcemia, which attenuate the cellular reaction to ADH--might be one of the causes. It must be noted that some decrease in potassium content of cells in the external layer of the renal medulla was demonstrated in rats after flights aboard biosatellites. No other changes had been found.

It is very important to study renal function and reactions to administration of hormones and loads (in particular, water and potassium) in order to comprehend the regulatory systems [52]. With such an approach, the kidneys can be used as sort of amplifiers, reflecting the essence of endogenous processes. The kidney is a fine indicator, which detects minimal changes and rapidly corrects them in order to maintain an optimum endogenous environment. One would think that it will be very important to use equipment for rapid determination of the composition of excreted fluid during long-term flights, for the purpose of analyzing processes in the body and promptly solving the problem of preventive measures.

The duration of man's exposure to weightlessness does not affect the condition of different physiological systems in the same way. At the early stages, redistribution of blood and vestibular disorders are of the greatest importance. Subsequently, the body adapts, the above changes revert to normal, but then changes begin to appear in the skeletomuscular system, which are attributable to the absence of gravity. These changes affect both the bones and muscular system. It is possible to curb somewhat the development of atrophic processes in most muscle groups by means of intensive physical exercise.

In our opinion, the changes in fluid-electrolyte metabolism are a reflection of the changes that are caused by weightlessness in the above-mentioned physiological systems and neuroendocrine mechanisms involved in these processes. In a very schematic form, it can be assumed that intensified loss of fluid, sodium and chlorine at the first stage of exposure to weightlessness is the consequence of inevitable redistribution of blood; increased excretion of potassium and its negative balance serve as a manifestation of progression of atrophic processes and change in cell metabolism. Increased

calcium excretion is due to impairment of normal metabolism of bone tissue. Finally, the negative balance of magnesium, phosphorus and sulfur is probably related to changes in both bones where these electrolytes are deposited and cells in a number of tissues. If this scheme is valid, the main line of preventive measures should take into consideration duration of exposure to weightlessness, as well as the causes of changes in fluid-electrolyte metabolism. During flights, the chief preventive measure should be to counteract development of atrophic processes. At the first and final phases of flight, agents that have opposite effects on the volume of extracellular fluid are probably indicated, and this should alleviate significantly the acute period of adaptation to weightlessness and readaptation to earth's gravity. As we have already noted, use of such preventive agents prior to landing the spacecraft yielded beneficial results.

The studies that have been conducted enable us merely to describe the status of the problem. Unquestionably, there is a need for in-depth analysis of metabolism of macro- and trace elements during weightlessness, evaluation of the distinctions of individual reactions and development of preventive measures for each phase of flight. The study of fluid-electrolyte metabolism, which yields an integral evaluation of several physiological systems, is important to an overall evaluation of the functional state of cosmonauts and determination of permissible time of man's exposure to weightlessness.

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PROBLEMS AND PROSPECTS OF SPACE PHARMACOLOGY

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 5, 1980 pp 10-20

[Article by V. S. Shashkov and V. V. Sabayev, submitted 22 Nov 78]

[English abstract from source]

The paper reviews the Soviet and foreign literature on the pharmacological support of manned space flights with emphasis on pharmacological prophylaxis and therapy of adverse effects of the space environment. The paper discusses future development of pharmacological studies as part of space medicine.

[Text] Much importance is attributed in the problem of assuring the safety of manned space flights (SF) not only to developing sets of physical preventive measures (exercises on simulators, electrostimulation, LBNP [lower body negative pressure], compensating suits, etc.), but to prevention of functional changes, as well as treatment of possible diseases with pharmacological agents.

1. Main Directions of Pharmacological Research in Space Medicine

A summary of the findings of medical monitoring and tests during SF, made by a team of specialists [1], revealed that exposure to SF conditions leads to changes in some physiological parameters, which include changes in functional state of the cardiovascular system, appearance of a set of symptoms similar to motion sickness, change in fluid-electrolyte balance, decreased mineralization of bone, changes in some biochemical parameters, reduction of muscle mass and body weight, anemic syndrome, diminished immunobiological activity, and others. All of these phenomena are reversible.

The question of using drugs in space medicine to prevent and treat the above adverse effects on the crews of manned spacecraft is the subject of animated discussion in the Soviet and foreign literature [2-12].

In view of the specific distinctions of the work of crews of aircraft, as well as conditions under which drugs may be taken by cosmonauts, a

number of authors have raised the question of the need to create a new branch of pharmacology, space pharmacology [4-7], or more precisely aviation and space pharmacology.

The effects of weightlessnes, which mankind encountered for the first time, are diverse, while the pathogenetic mechanisms of occurrence of some of them [13, 14] have yet to be demonstrated and defined. The severity of these phenomena is quite variable. It depends on the duration of SF, and it is largely determined by the individual listinctions of cosmonauts.

Extremely valuable information about the effects on man of weightlessness and other SF factors was obtained in the course of actual SF and as a result of examining cosmonauts during and after flights. Extensive studies with simulation of SF factors are also being conducted on the ground.

Unlike medical monitoring of man's physiological functions during a real flight, in the case of simulation of the biological effects of SF factors (each one separately, as well as combinations of factors), it is possible to conduct studies on different levels of organization of biological systems with the use of the latest methodological procedures.

The methods of modeling and simulating the effect of weightlessness on the body under ground-based conditions were systematized and submitted to critical analysis [14]. One of the means of simulation is to use pharmacological agents to exclude muscular function (muscle relaxants) in order to obtain functional disturbances of skeletal muscles and metabolic processes in muscles [15]. As for modeling the other SF factors (radiation, accelerations, altered gas environment, etc.), it is technically feasible to reproduce them over any range and on all levels under ground-based conditions.

The medical kits aboard Soviet and American space craft contained a relatively small assortment of drugs referable to the groups of cardiovascular, analeptic, analgesic, psychotropic, antibiotic agents, drugs for the prevention and treatment of "seasickness," vitamins, etc.

Drugs referable to the group of efficiency stimulators were first used during missions aboard the Apollo 7 and Apollo 8 spacecraft.

There were only 12 products aboard the American spacecraft, Gemini 7. Subsequently, the onboard medicine kits progressively increased in size, in both Soviet and American spacecraft [16-18]. There is also no question but that the assortment of drugs in future SF will grow, as indications for use thereof are defined, afterthey have been substantiated experimentally and submitted to special clinical trials.

However, it must be noted that the drugs traditionally used by physicians for diverse forms of pathology and functional disturbances cannot always

yield the desired preventive or therapeutic effect under such unusual conditions as SF, since the pharmacodynamics of drugs, reactivity of the body and pathophysiological mechanisms of the effect of weightlessness have not yet been fully disclosed. There is an obvious possibility of developing new agents for use under specific conditions of human vital function, which have the capacity to normalize physiological functions impaired by the habitat, which cannot be qualified as development of a pathological process, but which could prevent or make difficult the performance of programs or present a threat to man's health and safety during and after SF.

In accordance with the established practice of supporting SF, there are several stages: the period of preparing cosmonauts, lift-off and going into orbit, free SF, prelanding and landing periods, and support of the crew after returning to earth [6]. There are specific distinctions to the tasks of experimental and clinical pharmacology, depending on the phase of SF.

In the preflight period, determination is made of the assortment and amount of drugs required to support the SF, depending on the duration of the mission, its objectives and nature. It must be borne in mind that support of space missions with drugs is based on data referable to the prediction of functional disorders and probability of diseases with consideration of duration of SF, number of crew members and other conditions [18, 19]. In this case, one should adhere to the principle of extra supplies, not only with regard to amount and assortment of drugs, but with consideration of increasing their therapeutic "capacity," interchangeability, etc. [18]. Studies are made of individual drug tolerance, possible side effects (allergy, reverse effects, etc.). The cosmonauts are informed about the rules for drug intake, indications and contraindications. Special attention must be given to the possibility of an allergic reaction to drugs, determination of tolerable dosage for single and repeated intake. In the event of an adverse result of testing a product or combination of products, they are excluded from the medicine kits and replaced with others that are well tolerated.

During this period, particular importance is attributed to consideration of changes in reactivity to drugs in weightlessness and in the postflight period, when the gravity factor is again present.

There has been previous discussion of the changes in reactivity of mammals to drugs in an altered gas environment, in the presence of accelerations and radiation [4-7, 20].

It is becoming particularly important to test reactivity to drugs when simulating weightlessness, which determines the choice of dosage for the program of intake of a product during an actual flight. In view of methodological difficulties, this matter has still been studied very little. There are only a few publications, which report experimental findings on sensitivity of the body to drugs against the background of hypokinesia as an approximate model of weightlessness [7, 21-26].

The data obtained from animal studies do not solve the problem of choice and program for intake of durgs during SF and with exposure to other experimental factors, and they are indicative of a need to conduct new studies in this direction under experimental and clinical conditions.

In this regard, of great interest is a study of the distinctions of the effect of a combination of stimulants (caffeine + strychnine + phenamine) given to individuals who spent a long time under conditions of clinostatic hypokinesia [27].

It should be noted, once more, that in-depth studies of reactivity of the body to intake of drugs, with due consideration of changes therein during long-term SF, are necessary for scientific justification of recommendations concerning dosage and modes of administration of drugs for preventive or therapeutic purposes during SF [7].

We should dwell in particular on the prevention of infections in the preflight period. A number of authors [6] believe that the main task is to rid the organism of potentially pathogenic microorganisms situated on the skin, mucosa of the mouth, nose and respiratory tract, with concurrent disinfection of the gastrointestinal tract. Development of resistant forms of microorganisms, superinfection and side effects from preventive and therapeutic agents (chemotherapeutic products, antibiotics) presents a danger during long-term SF, due to decline of general reactivity. These authors justifiably recommend that drug forms of antiseptics, disinfectants and other agents suitable for use in weightlessness, with due consideration of individual distinctions of cosmonauts' microflora, be developed. These matters are the subject of research by specialists in the field of biopharmaceutics.

There are very many works dealing with the biological bases of gravitation, and they are covered the most thoroughly by A. G. Smitt [28], P. V. Vasil'yev and A. R. Kotovskaya [29], in a joint Soviet-American publication with extensive Soviet and foreign bibliography (247 and 250 items, respectively).

There has been previous comprehensive discussion [6, 7] of the questions and problems of pharmacological support of lift-off and landing of manned spacecraft with due consideration of the effects of accelerations, vibrations and other factors. In these works, there was analysis of studies of the means of enhancing resistance to the gravity factor, which were conducted in our country and abroad. From the pharmacological point of view, development of cardiovascular agents, use of antihypoxia agents and substances that prevent elevation of pressure in pulmonary vessels, reduce the tonus of the bronchi and secretion of bronchial glands are promising.

Of course, the development of special drugs for intake in the presence of accelerations should be combined with refinement of technical means of protection against them.

2. Pharmacological Support of SF

The biomedical studies conducted on the ground and during missions of the Salyut and Skylab orbital stations yielded extensive information about man's reactions to long-term weightlessness and other SF factors.

There are data pertaining to the reactions of different physiological systems or the entire body at different phases of SF and in the postflight period. This made it possible to describe in general terms the main sets of symptoms that are distinctly manifested during SF and that require development of preventive and therapeutic agents [13].

Motion sickness: The set of symptoms that is outwardly similar to that of seasickness is known under the name of "motion sickness" (MS), "kinetosis" and "seasickness." This syndrome, which is more or less marked in different cosmonauts, usually appears within the first 7 days of SF. It has been described in detail previously in relation to development of preventive agents [7]. In spite of the rather rapid adaptation of the vestibular analyzer to weightlessness, the manifestations of MS have a significant effect on performance and vital functions of spacecraft crews during the importnat first phase of an orbital flight. Symptoms of illusory sensations and MS in flight were noted in virtually all 33 American cosmonauts and the crew of the Apollo spacecraft. There was an attack of MS during the third flight aboard Skylab. Analogous changes in vestibular reactions were also observed during the flights of Soviet cosmonauts [13]. There is an extensive Soviet and foreign literature, which was recently analyzed [30], dealing with the etiopathogenesis of MS.

Many products and combinations thereof have already been tested as means of preventing and treating MS [7, 31-34]. The success of a rational search for agents to control seasickness is largely related to a proper choice of experimental method.

As applied to man, the method of quantitative evaluation of the efficacy of drugs is the most informative, when tests are made in a slowing revolving system [35] and the double blind method is used.

It must be noted that there are special requirements, which limit the choice of agents, that are made of products intended for the prevention and treatment of vestibular disturbances in man when he is in spacecraft and other moving systems that require a high precision to control them. At the same time, it is obvious that such products must be developed by means of combining drugs referable to different classes. This is all the more understandable, since a set of physiological and biochemical factors, the essence of which has not yet been identified, plays the leading role in the pathogenesis of MS [36].

Graybiel [37] considers the following to be the most important conditions for studies dealing with the search for products to prevent MS: screening

of clinically healthy subjects to be used in such studies, reliable recording of linear and angular accelerations, standardization of laboratory conditions, measurement of evoked reactions, use of appearance of vomiting as a criterion of the range of resistance to MS and mandatory use of a double blind control when testing drugs.

Functional changes in the cardiovascular system in SF: The first American cosmonaut-physician, Kervin stated [38]: "When man finds himself in weightlessness, he begins to feel very distinctly that profound changes are taking place in his body. There is the strange sensation of filling of the head, nasal congestion, and speech acquires a nasal tone. The faces of his comrades appear puffy."

Deconditioning of the cardiovascular system is typical of SF and prolonged hypokinesia.

Hyperemia of the face, development of edema of the nasopharynx and facial tissues in weightlessness can be attributed to redistribution of blood [39].

A large group of American specialists [40] believes that appearance of the above changes under the effect of prolonged bed rest and in SF is related not only to a low hydrostatic pressure, but muscular atrophy, decreased efficiency of the muscular pump and decreased volume of circulating blood perceived by baroreceptors.

All these changes can be qualified as development of deconditioning of the cardiovascular system during SF and prolonged bed rest in antiorthostatic [head down] position [41].

In general, the tasks for pharmacology and its role in the prevention and treatment of cardiovascular changes can be formulated as the search for agents to normalize the redistribution of blood, eliminate stasis in the basin of the pulmonary circulation and circulatory system of the brain, prevention of functional cardiac disturbances, enhancement of orthostatic stability, etc. The study of the use of drugs in a set of therapeutic and preventive measures merits special attention. Here, evaluation of agents used to prevent and treat arrhythmia, cardiotonic agents, substances that affect the energy resources of the myocardium is of serious importance. For example, it has been demonstrated that Isoptin enhances man's physical fitness in the presence of antiorthostatic hypokinesia, it improves functional parameters of the cardiovascular system and orthostatic stability [42].

In view of the role of adrenergic regulation of circulation, in particular cerebral circulation [43], of great interest to space pharmacology are drugs in the group of α- and β-adrenoblocking agents, sympatholytic, myotropic agents and rational combinations thereof. Products with a β-adrenoblocking action are considered to be agents that prevent myocardial infarction or cardiac rhythm disorders in the presence of prolonged emotional stress [44] and orthostatic instability.

The skeletomuscular system: Muscu'ar atrophy and decrease in volume of musculature occur in weightlessness and with different forms of prolonged hypokinesia. Gradual atrophy of skeletal muscles is one of the most consistent consequences of weightlessness [45].

It has been demonstrated that during SF and prolonged hypokinesia the bones are decalcified, and this is a typical manifestation of atrophy of skeletal tissue [46-50].

In a survey dealing with the effects of weightlessness on the human skeleton [49], the authors estimated that during SF a loss of Ca constituting 1-2% per month will take place continuously for 1 or several years. The opinion is held that Ca loss may affect the mechanical strength of the skeleton [51], and becuase of increased passage of Ca into blood it can lead to functional disorders of cardiac automatism, conduction of excitation, blood coagulation, etc. [52, 53].

There are three basic possibilities of affecting processes of decalcification of skeletal bones during prolonged hypokinesia: balanced diet, physical exercise and drugs.

At the present time it has been shown that there is an imbalance between metabolism of Ca in labile and stable components during prolonged hypokinesia: reduction of the rapidly metabolized stock of mineral salts in bone tissue and onset of relative and absolute prevalence of the slowly metabolized stock. Development of osteopathies with retention of supporting function of the skeleton during prolonged hypokinesia is attributable to inhibition of osteogenesis, which leads to atrophy of the bones, as a result of activation of resorptive processes with concurrent depression of bone tissue synthesis [54].

It may be assumed that muscle tone is an important factor in changes in Ca metabolism, since there is a satisfactory correlation between extent of osteoporosis and changes in muscular mass.

As we know, Ca metabolism in the body is controlled by parathyroid hormone (PH)and thyrocalcitonin (TCT).

Taking into consideration the mechanism of action of these hormones, efforts were made to provide experimental justification for use thereof as the means of prevention of disturbances of Ca metabolism during hypokinesia [54-60].

The cited studies are indicative of the need and potential of searching for pharmacological agents to normalize Ca metabolism in the body. However, the combined effect of isometric exercises, physical work-out with the use of drugs affecting mechanisms of development of functional changes in the skeletomuscular system in weightlessness will probably be found to be the most effective.

Changes have been demonstrated in fluid-electrolyte metabolism during SF [13, 61, 62]. We must mention activation of glucocorticoid function of the adrenal cortex during flights, as confirmed by an appreciable increase in excretion of 11-HCC [hydroxycortisteroids] and total 17-HCC in urine. Analogous findings were made in studies involving long-term antiorthostatic hypokinesia [63, 64]. Use of a set of pharmacological agents (strychnine, ephedrine and phenibut) under hypokinetic conditions attenuated the above hormonal changes [64].

After participating in flights varying in duration, cosmonauts presented marked dehydration and loss of electrolytes as a result of increased diuresis and excretion of sodium during the flights. Fluid loss is one of the causes of weight loss, which was demonstrated after flights and after termination of studies with simulation of the effects of weightlessness [13, 61, 65]. These phenomena are associated with electrolyte loss, in particular, Na, K and Cl [39, 66, 67].

In the opinion of a number of specialists [68-70], one of the main causes of fluid loss in flight is increased diuresis as a result of depression of ADH secretion and aldosterone production, which leads to an increase in permeability to fluid of the distal segments of the nephron and an increase in excretion of water. This view was corroborated in ground-based studies with simulation of the effects of weightlessness [71, 72].

Vasopressin (pitressin) [73], which by activating hyaluronidase increases the permeability of the walls of renal tubules to water, causing reabsorption thereof in peripheral segments of the nephron [74], was tried as a means of normalizing some parameters of fluid-electrolyte metabolism under hypokinetic conditions. It must be borne in mind that vasopressin inhibits diuresis only if there is hyperfunction of the kidneys [75].

Tests were made of 9-α-fluorohydrocortisone (9-FC) [55-57, 76, 77] to restore fluid-electrolyte metabolism, prevent plasma and weight loss, and eliminate other changes caused by bed rest.

There is information to the effect that pituitrin R, DOKA [perhaps typo for DOKSA--desoxycorticosterone acetate?] and nerobol [methandrostenolone] are beneficial to fluid-electrolyte metabolism [65].

Thus, the problem of developing pharmacological agents for the prevention and treatment of changes in fluid-electrolyte balance and other metabolic changes in man during SF has not yet been solved.

Performance stimulators: There are studies of this problem, which have been analyzed in several works [7, 78-80].

Among the most popular and active stimulants of efficiency and operator performance, we should include phenamine, centedrin (ritalin, meridil), reactivan, mefaxamide, duklidin, panklar, katovit, tosolin and others.

These agents (particularly the phenylethylamine derivatives) have been studied rather well, and they are used extensively as performance stimulants.

V. M. Vinogradov believes that phenamine may be used as a means of "emergency" increase in efficiency, mainly in cases of a "nervous" rather than "muscular" nature [6].

In recent years, there have been reports about a new class of stimulants, a representative of which is gutimin [guanylthiourea] [6, 81].

With regard to phenylethylamines as stimulants, ephedrine has been given unjustifiably little attention.

Although strychnine is usually not given as a stimulant, there are data indicative of its capacity to enhance the body's resistance to SF factors [82], as well as physical loads [83]. For this reason, we consider it justified to continue with experimental studies of the stimulating properties of ephedrine, strychnine and combinations thereof [84].

The general tonics, such as ephedrine, strychnine and caffeine, are quite physiological. Their main action is directed toward stimulating metabolism and efficiency of the body [85-88].

The problem of increasing efficiency by means of pharmacological agents is not limited to the search of only synthetic stimulants. In the last 10 years, there has been a tendency toward the study and use of tonics of plant and animal origin during intensive physical exercise [89-91].

Interest is growing in compounds that enhance production of energy, substrates of biochemical processes and vitamins as stimulants. This is quite understandable, since the expenditure of compounds with a macroergic bond in functional systems is one of the chief causes of fatigue.

Stimulants, adaptogens and "mild" tonics are recommended when it is necessary to increase the efficiency of cosmonauts.

In the event of a need to drastically increase efficiency, one may consider the use of "superdoping" agents, adaptogens and agents that stimulate redox processes in tissues.

We cannot rule out the use of pharmacological agents when the cosmonauts return to earth after long-term missions [3, 92].

Evidently, long-term space flights will be associated with relative social isolation, gradual decline of interest in the surroundings due to habituation to them, monotony, change in physical condition under the influence of weightlessness and change in the general correlation between various modalities of sensory information [40].

These phenomena, which reflect signs of nervous and emotional tension, as well as fatigue, have not yet had an appreciable effect on the outcome of flights.

Laboratory studies of the effects of isolation revealed sleep disturbances. The severity thereof increased with increase in duration of isolation [40]. There are reports of some changes in sleep of cosmonauts who participated in long-term missions [93].

There has been rather comprehensive study of the question of developing psychosedative agents [7, 80]. It must merely be noted that, in choosing psychosedatives, one should give preference to agents with minimal or no adverse effects on the speed and accuracy of mental reactions, on the parameters of cardiovascular function and muscle tone.

Weightlessness and related changes in impulsation from proprioceptive and exteroceptive receptors, as well as altered afferentation from muscles [94], are the chief factors that could cause substantial changes in the quality and duration of man's sleep during SF, correlation between its stages and depth, in addition to the distinctions of the work and rest schedule.

Of the large group of hypnotics, for use during SF preference should be given to agents that affect mainly the falling asleep phase and induce sleep that is as close as possible to physiological sleep [6], as well as to "daytime" tranquilizers, which can be viewed as the "hypnotics of choice." It is believed [7] that sedatives with moderate duration of action are the most promising for intake during SF. Long-acting sedatives have side effects, due to their slow elimination and accumulation in the body.

One should adopt a very cautious attitude toward the use of sedatives, particularly under SF conditions. Many of them alter significantly the nature of an individual's typical sleep, and not infrequently they lead to loss of effect after prolonged intake [97].

Thus, the data available to date are indicative of the possibility of making effective use of drugs to enhance resistance to the extreme SF factors. At the same time, the choice of drugs for onboard medicine kits requires experimental substantiation, with due consideration of the possible specifics of their effects on the body in weightlessness, possible side effects, mode of intake, shelf life, possibility of being taken many times, etc. It is also imperative to synthesize new specific agents followed by the laborious process of experimental and clinical studies thereof.

It must be borne in mind that we did not discuss here analgesics, antipyretics, antihistamines, radioprotective, antitussive, anesthetic, laxative and other drugs, liquids for parenteral injections, that have

been and will continue to be included in the onboard medicine kits. There are publications by Soviet and foreign authors on these questions [5-7, 9, 18, 96-99]. But, even with regard to the above-mentioned special problems of space pharmacology, special studies of the specific conditions of space flights are needed.

It must be stressed that the advances in space medicine have helped solve a number of problems of medical science as a whole [1]. This applies to determination of the boundary between normal and pathology, refinement of methods of expert evaluation of man's health status, development of miniaturized and precise equipment with continuous biotelemetric transmission of information, etc. There is no question but that space pharmacology will also make its contribution to the development of experimental and clinical pharmacology.

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EXPERIMENTAL AND GENERAL THEORETICAL RESEARCH

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BIORHYTHMOLOGICAL STATUS AS ONE OF THE CRITERIA FOR COSMONAUT SCREENING

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 5, 1980 pp 20-24

[Article by S. I. Stepanova, submitted 29 Oct 79]

[English abstract from source]

The concept of biorhythmological status of the human body understands it as a sum total of biorhythmological characteristics of the organism. The status is discussed in two aspects: constancy and variability of circadian rhythms of vital functions. The relationship between the two parameters is described in the light of a hierarchic structure of the circadian system. The dependence of stress-resistance upon integrity and level of organization of the circadian system is ascertained. The importance of assessment of biorhythmological status for proper cosmonaut selection is emphasized.

[Text] The dialectical unity of mutually exclusive elements of vital processes--anabolism and catabolism, building and destruction--is manifested in the rhythmic nature of functions on levels of living organisms [1]. From the standpoint of organization of vital processes in time, the organism is a system of rhythms having the most varied periods, ranging from fractions of a second to several years. In man, the circadian rhythms, which have a period that corresponds to the 24-h cycle of activity--sleep and waking cycle, are the leading and best studied ones. There is reason to believe that all of our functions are governed by circadian rhythms. It is expressly this universality of the circadian rhythm, its involvement in all vital processes, that caused the distinction of circadian rhythms in a separate group, close studies thereof, and on the basis of the latter the conception emerged of the organism as a system of circadian rhythms. It is expressly within the framework of such a conception that the concept of biorhythmological status of the organism was formulated.

The results of numerous studies of circadian rhythms of man and animals revealed that the elements of these rhythms are subject to appreciable individual variations within the framework of the same biological species. It was noted, in particular, that the circadian system does not change at the same rate in different individuals after there is a shift in the phases of the sleep--waking rhythm: some adapt to such shifts faster, others more slowly. Similar findings have been made with regard to adjustment to

working in shifts and at night: some people adjust easily, while others experience considerable difficulties, get sick and ultimately change to daytime work. Evidently, the circadian system of individuals who adapt well to changes in the sleep-waking cycle is more flexible. Since unusual schedules were used in manned space flights until recently, of course individuals with a flexible circadian system were the most suitable to participate in them. However, the direct method of assessing flexibility [mobility, lability] requires much time (the phase of the sleep-waking rhythm must be shifted, then the adaptation process has to be monitored for 2-3 weeks). Consequently, one must search for other criteria of flexibility. In the course of our work, the hypothesis was expounded that the individual degree of coordination of circadian rhythms and proper correlation between them have a direct bearing on flexibility of the circadian system. In very general terms, it was believed that well-organized and orderly function of the system of vital rhythms, including great flexibility of this system, depends on the quality of each rhythm in this system, stability of quantitative characteristics of its parameters as recorded from cycle to cycle and, primarily, on the stability of the position of acrophases on the time scale. From this vantage point, which we adopted initially, good reproducibility of the parameters of circadian rhythms in the course of long-term observation is an indicator of coordination of the body's circadian system. In our studies, this property was named constancy and in the work of Cornelissen et al. [2], biostability.

Thus, according to our initial conceptions, a circadian system with constant rhythms should, other conditions being equal, be more flexible than one with labile rhythms. However, the results of subsequent studies revealed that one should approach evaluation of the correlation between constancy and lability with consideration of the hierarchic structure of the body's circadian system. According to current conceptions of the circadian hierarchy, there is a master rhythm [driving rhythm] or, perhaps, a group of master rhythms at its top, which control subordinated following rhythms. The purpose of the master rhythms is to link the body with the outside world, with phasic synchronization of vital rhythms with physical ones and, when dealing with man, social timers. The phases of the master rhythms are controlled by timers, while those of the following rhythms are adjusted by the master rhythms, which transmit exogenous signals to underlying "stories" [levels]. This transmission occurs successively, from one level of the circadian system to another, from higher ones to intermediate ones, and from them to the deepest "hidden" processes. The speed of transmission of control signals from top to bottom is determined by the coordination of the transmitting system and good coordination of the function of all its elements.

From the standpoint of optimum function of the body's circadian system, there are various requirements made of the constancy of master rhythms and followers. Master rhythms must be sensitive to exogneous signals, capable of rapidly responding to these signals by changing numerical values of its parameters, i.e., they must be quite labile, for successful

communication between the environment and the body. On the other hand, the speed of the body's reaction to a change in parameters of the pacemaker is all the higher, the more stable the correlation with following rhythms in the realm of which transmission of the signal from "story to story" chiefly occurs. The stability of this correlation is determined by the degree of their constancy. A high constancy of following rhythms provides for rapid and accurate transmission of signals from one level of the circadian system to another, rapid adaptation of the body to a new position of the timer phase. However, it would hardly be correct to believe that the adaptive capabilities of the circadian system increase with increase in lability of master rhythms and constancy of rhythm followers. Such a conception erects a barrier between the two "stories" of the circadian system, separates them and creates the impression that they are functionally divided. Evidently, all of the "stories" on the hierarchic ladder of circadian rhythms are subject to reciprocal influence: the lability of master rhythms that are closely linked with rhythm followers is transmitted in part to these subordinate rhythms. The following rhythms, which interact with the master rhythms, impart their constancy to the latter to some extent. One would think that the perfection of functional organization of the circadian system is attributable to a certain correlation between lability of the pacemakers and constancy of following rhythms, a combination of rather high sensitivity of the system to exogenous signals, rather distinct and rapid transmission of these signals to the lower "stories."

The conception of master and following rhythms was developed by Pittendrigh, who wrote that "... the role of a light-sensitive master [driving] oscillator consists of maintaining (perhaps with the involvement of some other systems) the necessary phasic correlations in the rest of an organism, which is done by extending all other oscillations" [3, p 87].

This conception corresponds in essence to the thesis of P. K. Anokhin, which he formulated, it is true, on a somewhat different plane. According to this thesis, "... the functional system contains at least two categories of physiological mechanisms with very different physiological properties. One of them contains mechanisms that are extremely conservative ... and relatively conservative.... Other key mechanisms of the system ... are extremely flexible..." [4, p 36].

A differentiated approach to evaluation of constancy, with consideration of the place of the rhythm under study in a controlling or subordinated element of the circadian system of the body enables us to understand why some authors find a positive correlation between constancy and mobility of the rhythms studied, while others, on the contrary, find it between lability and mobility. On this basis, one can assume that the former are dealing with following rhythms and the latter with master rhythms.

It must be stressed once more that the circadian system is best organized when a rather high constancy of following rhythms is combined with rather

high lability of master rhythms. The following principle is entirely valid for such a system: the better the system is organized, the more adaptive it is. A. B. Georgiyevskiy et al. write that "The better organized systems are usually also better adapted; in other words, adaptation emerges as a criterion of degree of organization and vice versa" [5, p 59]. Here, the authors indicate that the concept of "organization" does not refer to morphophysiological structure, but to the orderliness of interaction within the system and with the conditions surrounding it. From the standpoint of this principle, a well-organized circadian system must be highly adaptable, not only to a shift of the sleep-waking cycle, but to any stressor that disrupts the phasic architectonics of circadian rhythms. In other words, a well-organized circadian system must be resistant to desynchronosis caused by any stress agent, including such serious agents in space as weightlessness.

It is believed that the mechanism of the biological clock that controls circadian rhythms of the body is located in the hypothalamus. Several researchers classify the sleep-waking rhythm as a master rhythm, attributing prime significance to it in regulating circadian biological rhythms. However, is it valid to speak of an extremely "rigid" hierarchic structure of vital rhythms of the body, independent of the specific conditions of its existence and, consequently, of the unchanging location of each rhythm in this structure? This is unlikely. Evidently, the circadian system of the body, like every other one, is flexible, and this flexibility is manifested, in particular, by the fact that the place of the rhythms on the hierarchic ladder changes, depending on the concrete conditions. If, in our everyday life, we go to sleep and wake up on the basis of internal influences reflecting the daily dynamics of intimate processes in the body, it is apparent that the rhythm of these influences is primary in relation to the sleep-waking rhythm. A different situation arises after a transmeridional flight: the internal inducements to sleep and stay awake no longer conform with local time, and one has to plan one's sleep-waking schedule in spite of these internal signals for speedy adjustment to the new living conditions: one must go to bed and get up when it is required, rather than when one wants to. In this case, the appearance of a new rhythm of activity and rest occurs by means of volitional commands to onself, which compel one to go to bed and get up at an unaccustomed time, requiring active wakefulness and rest, in spite of how one feels. Thus, the newly formed rhythm of mental processes advances to the head of the circadian hierarchy; this is the process that controls the rhythm of activity and rest which, in turn, becomes the driving rhythm for all other rhythms of the body, including the most intimate ones. After completion of adaptation, there is restoration of the original hierarchic structure of circadian rhythms. Of course, such a conception of flexibility of the circadian system is hypothetical to some extent.

It must be noted that the constancy of the circadian system of the body fluctuates over a seasonal rhythm. Numerous experimental data obtained from studies of animals and man made it possible to formulate the conception

of so-called seasonal physiological desynchronosis, according to which there is a decrease in constancy of the circadian system of people who live at temperate latitudes in the transitional times of the year, in the spring and fall, and an increase in contrasting seasons, summer and winter [6]. One would think that seasonal physiological desynchronosis is associated with decrease in the body's resistance to deleterious factors, and that it causes exacerbation of chronic diseases in individuals who suffer from them (for example, duodenal ulcer). Interestingly enough, the physicians of past years apparently knew that the well-being of an individual could worsen in the spring and fall, and they recommended "general cleansing" of the body in the spring and autumn [7, p 149].

On the basis of conceptions of individual levels of lability and constancy of the circadian system, a general concept was formulated of the individual biorhythmological status of the body as an aggregate characteristic of its biorhythmological distinctions. Mobility [lability] and constancy are different aspects of the biorhythmological status which, of course, do not limit the content of this concept. The conceptions that are being developed concerning the biorhythmological status can serve as the basis for practical measures referable to biorhythmological screening of cosmonauts who are the most resistant to the stress factors of space flights, meaning not only a shift in the phase of the sleep-waking rhythm, but others, including weightlessness. At the present time, not only theoretical, but applied approaches have been worked out to assess constancy, which make it possible to express it quantitatively [8]. Evaluation of constancy, lability and (which is even more important) general adaptability of the body, its resistance to "space" stressors must be included in the screening program for candidates for space flights.

Another very important distinction of man's individual biorhythmological status is the relation of his maximum efficiency to a given time of day. People can be divided into three types according to this feature: "larks," who have peak efficiency in the morning, "owls," who have peak efficiency at night, and individuals with maximum efficiency in the middle of the day. Determination of this individual biorhythmological distinction of each crew member will make it possible to set up the most rational work schedule for each of them, having the most responsible operations coincide with the period of their peak efficiency.

The question of biorhythmological screening of cosmonauts is acquiring particular urgency in view of the increased duration of manned flights and prospects of exploring planets in the solar system. It is a pressing task for space medicine to implement it in practice.

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STUDY OF THE COMBINED EFFECT OF ANTIORTHOSTATIC POSITION AND LBNP ON MAN'S TRACKING ACCURACY AND SPATIAL ORIENTATION

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[Article by B. B. Bokhov, B. B. Yegorov, A. A. Savilov and Yu. N. Taranenko, submitted 13 Feb 79]

[English abstract from source]

Test subjects exposed to a head-down tilt at -30° for an hour participated in the experiment. The use of LBNP during tilting improved precision of arrow orientation on the round-shaped screen (during continuous tracking) but did not influence orientation relative to the gravitational axis and the long axis of the body. The selective effect of LBNP on the orientation can be attributed to the increased importance of inner coordinates due to the pressure of inferior walls of the LBNP suit on the foot surface and blood pooling in the dependent part of the body.

[Text] Previous studies revealed that a prolonged stay in antiorthostatic [head tilted down] position causes man to make more mistakes in spatial orientation. Deterioration of accuracy of orientation was attributed to stimulation of mechanoreceptors by the hydrostatic pressure of the column of blood in static zones [1]. If the hemodynamic changes are viewed as one of the causes of spatial illusions during space flights [2-4], factors that normalize the distribution of blood in the body could be used as an effective means of eliminating or attenuating symptoms of spatial disorientation.

On the basis of the foregoing, our objective was to investigate the possibility of compensation of sensory changes caused by antiorthostatic position (as a model of weightlessness) by means of LBNP [lower body negative pressure].

Methods

We used the following functional tests of spatial orientation: accuracy of setting an indicator pointer in relation to a turning reference pointer,

Table 1. Effect of antiorthostatic position, LBNP and position of display pointer in relation to operator on his tracking performance

Factor	Antiorthostatic position (-30°)						Combination of antiorthostatic position (-30°) and LBNP (40 mm Hg)					
Initial position of pointer	parallel to subject's axis			vertical			parallel to subject's axis			vertical		
Minute of test	5	30	55	5	30	55	5	30	55	5	30	55
Points	1	2	3	4	5	6	7	8	9	10	11	12
Reaction time, s	7.0±0.2	7.0±0.3	6.9±0.2	8.3±0.3	8.1±0.2	8.1±0.3	6.7±0.3	6.6±0.3	6.5±0.3	7.8±0.2	7.8±0.2	7.9±0.2
Tracking error, °	4.2±1.8	4.6±1.5	5.1±1.6	2.4±1.8	5.8±2.3	5.6±1.6	5.7±0.7	7.6±1.1	4.4±1.8	5.5±1.8	4.2±1.7	3.8±0.[illegible]

gravitational vertical and longitudinal axis of the body, as well as accuracy of subject's evaluation of his position in relation to the horizontal line.

To study tracking performance, we used a portable instrument specially designed for this purpose. The Vertikal' instrument was used to test spatial orientation [5]. The instruments were installed in front of the subject, on a table that is used to tilt the body in a frontal plane. The subject's visual field was limited by a rectangular chamber (1 m^3), open at the bottom, which was also attached to the turntable. Thus, the entire arrangement of the subject, instruments and chamber constituted a single system that could be rotated in the frontal plane.

The display part of the instrument used to test tracking performance consisted of two round screens. A pointer was installed on each of them, and it could turn about the axis. When turning the pointers, the subject had to keep them parallel. The reference pointer had to be turned upon instructions from the researcher with concurrent switching on of an electronic clock. There were two baseline positions for the reference pointer: in one position, it was set parallel to the longitudinal axis of the subject's body (during rotation it was in the left upper quadrant of the screen) and in the second, it was vertical (during rotation it was in the right lower quadrant of the screen). The reference pointer was turned in accordance with a preset program 90° to the left at the rate of 8 degrees/s. The subject controlled rotation of the indicator pointer (at the rate of 12 degrees/s). The electronic clock was started at the moment the subject depressed the button to turn the indicator pointer. Both pointers and the electronic clock were automatically stopped synchronously the moment the

subject released the button on the console. After the test, we recorded overall reaction time and magnitude of tracking error, an indicator of which was the angle of discrepancy between the two pointers. The intensity of illusion of body position in space was evaluated by the subject with his eyes closed, in degrees of the angle of seeming deviation of the longitudinal body axis from the horizontal line at the moment of moving from antiorthostatic to horizontal position.

We conducted two series of studies, control and main. For 1 hour, the duration of the test, the subjects remained in antiorthostatic position (-30°). In the main series, antiorthostatic position was combined with LBNP [lower body negative pressure] (rarefaction of 40 mm Hg). The subjects were in horizontal position while pressure was equalized in the pressure ["vacuum"] suit after termination of the test. Tests were run in the 5th, 30th and 55th min of the study. A vacuum suit [6] was used to create LBNP.

The method of comparing increment curves, as well as the t criterion for comparing pairs of samples, were used to process the results [7].

In all there were eight subjects in these studies, who were trained in advance to operate the equipment and were acquainted with the effects of LBNP.

In both series, we recorded the subjects' arterial pressure and heart rate during and after the study.

Results and Discussion

The objective of the tracking test included demonstration of reaction time as a function of orientation of the reference pointer in relation to the subject's body (Table 1). When the reference pointer was initially parallel to the subject's longitudinal axis the tracking error was less marked than when it was initially at an angle of 120° to the body axis ($P<0.01$). These data confirm the well-known thesis that optimum conditions for perception of the angular position of revolving pointers are created when the pointers are near points corresponding to 9 and 12 o'clock [8]. It was also previously demonstrated that an observer evaluates the position of indicator lines in coordinates of earth's surface or coordinates of a cockpit and body fixed in relation to it depending on the situation and instructions [9-11]. The established fact that the reaction time is the shortest when the reference pointer is parallel to the body axis indicates that the subjects also use the optical lines of a chamber as a reference system for spatial orientation of the longitudinal axis of their body.

A comparison of growth curves plotted for points 1, 2, 3 and 7, 8, 9 (see Table 1) established that reaction time was reliably shorter with LBNP than in the control series ($P<0.01$). A comparison of the curves plotted for points 5, 6 and 11, 12 revealed that tracking error diminished in the second half of the study period in the main group, as compared to the

control (P<0.05). The data indicative of improved operator performance with LBNP can be interpreted as the consequence of increased afferentation, from the mechanoreceptors of the lower extremities, particularly due to pressure of internal surfaces of the suit on the feet. It is a known fact that close contact of the body with support surfaces is one of the main factors that have a beneficial effect on reliability features of pilot and cosmonaut professional performance [12, 13]. Perhaps the mechanism of these influences are based on more acute perception of internal coordinates and body schema as a whole.

We observed a typical illusion, which consisted of seeming deviation of the body so that the head appeared above the horizontal line, both before and after equalizing pressure in the suit of subjects lying in horizontal position with the eyes closed. Evidently, this effect was related to efflux of blood from the top half of the body. Previous studies demonstrated that the intensity of this illusion is related to magnitude of rarefaction (and volume of deposited blood) [14].

In this study, after the subjects were returned to horizontal position the magnitude of illusory deviation of the body from the horizontal line constituted 41±6.3° in the control series. In the main series, the angle of illusory deviation of the body from the horizontal line constituted 26±2° with negative pressure in the suit, and this parameter changed insignificantly (29±2.9°) after equalizing the pressure. A comparison revealed a reliable difference between evaluations of the illusion in the control and main series (P<0.01).

On the basis of the foregoing, the decrease in angle of illusory deviation of the body in the main series can be explained as follows: LBNP reduces the volume of blood deposited in the top part of the body in antiorthostatic position and, consequently, it attenuates the effect of the hydrodynamic wave and the illusion, which occurs under its influence, of deviation of the body in space when the subject is moved to horizontal position. Moreover, there is accumulation of about 500-600 ml more blood in the vessels of the lower half of the body [14], which leads to stimulation of mechanoreceptors of areas of stasis. This could explain the decrease in tracking errors by the end of the study period.

Unlike the changes described above, there was virtually no change in orientation in relation to the vertical plane and midline of the body in response to LBNP (Table 2). This confirms the thesis that visual orientation in relation to a revolving pointer (tracking) and orientation in relation to the gravitational vertical and body midline are controlled by different systems.

It is known that man's visual orientation in relation to the vertical plane depends on the position of the main lines of the visual field [15]; in this case, on the position of the geometric lines of the rectangular chamber, which forms an angle of -30° with the physical coordinates of the vertical and horizontal. This is indicated, in the first place, by

the size of the angle of shifting of the subjective vertical in the direction of inclination of the chamber (to 27°) and, in the second place, by the error, which was stable throughout the study period, of determination of the vertical and midline of the body. A significant deviation of the subjective vertical in the direction of inclination of the chamber indicates that mechanoreceptors play only a secondary role in this task. Predominance of the visual rating system led to the seeming shift of the midline of the torso in the direction of inclination of the chamber. Under these conditions, relatively mild stimulation of the mechanoreceptors of the lower half of the body, induced by the suction effect of LBNP, had no appreciable effect on orientation.

Table 2. Effect of antiorthostatic position, LBNP and position of main lines of visual field on orientation in relation to the gravitational vertical and midline of the torso

Factor	Antiorthostatic position (-30°)			Combination of antiorthostatic position (-30°) and LBNP (40 mm Hg)		
Minute of test	5	30	55	5	30	55
Point No	1	2	3	4	5	6
Error in determination of vertical, °	−23.0±[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	−23.0±1.0
Error of determination of body midline, °	−6.5±1.6	−6.9±1.0	[illegible]	[illegible]	[illegible]	−7.1±2.2

Note: The symbol "-" signifies a shift of the subjective vertical (or median) to the left of the gravitational axis (or midline of the body).

However, the distinctions of operator performance (use of round screen, rotation of indicator pointer, continuity of tracking) depended more on the geometric lines of the chamber as a reference system, as well as the internal system of coordinates [8], upon which LBNP (40 mm Hg) apparently had an appreciable effect.

Consequently, LBNP, which was used to compensate for hemodynamic changes, selectively affected different types of orientation in space. Optimum conditions were created for the form of orientation upon which operator performance is based.

Thus, the results of this study warrant consideration of LBNP, not only as a means of preventing hemodynamic disorders in weightlessness, but as a possible means of optimizing performance pertaining to the control of spacecraft.

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CIRCULATORY REACTIONS OF FIRST CREW OF THE SALYUT-6 ORBITAL STATION TO FUNCTIONAL TEST WITH LBNP

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 5, 1980 pp 29-32

[Article by V. A. Degtyarev, L. Ya. Andriyako, V. M. Mikhaylov, V. N. Ragozin, Zh. G. Adamchik, I. V. Alferova, V. A. Andretsov and A. N. Kozlov, submitted 1 Feb 79]

[English abstract from source]

During the first two weeks of space flight the crewmembers showed circulation reactions to LBNP that were typical of reduced orthostatic tolerance. At later flight stages (beginning with mission day 49) the Commander displayed a gradual recovery of the cardiovascular function. The Flight Engineer exhibited reactions indicating his decreased tolerance of LBNP tests.

[Text] Use of the test with LBNP [lower body negative pressure] aboard orbital stations revealed that it is quite informative for predicting orthostatic stability of cosmonauts. In tis report, we submit the results of a study of circulatory reactions to a functional test with LBNP, conducted on the crew of the first main expedition that performed a 96-day space flight aboard the Salyut-6 orbital station.

Methods

We used the Chibis, protective pressure suit to create LBNP. The line where the [vacuum] suit was sealed was on the level of the crests of the iliac bones. During the test (background 5 min, rarefaction of 40 mm Hg for 20 s, 25 mm Hg for 2 min, 35 mm Hg for 3 min and recovery for 5 min) we recorded on the onboard Polynome-2M equipment a set of parameters of the cardiovascular system which was described previously [1, 2]. We measured the heart rate (HR), minimum (MnAP), mean (MAP), lateral systolic (LsAP), end systolic (EsAP) and pulse arterial pressure (AP), duration of phase of isometric contraction and period of expulsion of blood (PEB) by the left ventricle. We calculated the rate of propagation of the pulse wave (PWPR) over the descending aorta, stroke and minute circulation (SV, MV), specific actual vascular resistance to blood flow, as well as a number of interphase parameters.

The inflight data were compared to the results of preflight tests, which were conducted with the subjects in horizontal position. We analyzed the absolute maximum deviations of the parameters with the use of LBNP and relative changes therein (as percentage of mean base values). The commander (CDR) was examined 4 times before the mission (8 and 6 months, 13 and 5 days before it) and the flight engineer (FLE) twice (20 and 5 days prior to the flight). During the flight, tests with LBNP were made on both crew members on the 14th, 49th, 60th, 77th and 92d days, then on the 3d and 11th postflight days.

Results and Discussion

The first test with LBNP made in the 2d week of the mission revealed a more marked reaction of the circulatory system to induced redistribution of blood than before the flight. In this test, the CDR presented maximum changes in HR, phasic structure of the left ventricular systole, SV, MV, PWPR and AP; the FLE presented analogous changes, but somewhat less marked (Tables 1 and 2). Evidently, the tests made at this stage of the mission reflected the general pattern of reactions to LBNP in the case of incomplete adaptation to weightlessness [3], when the parameters of physiological reactions to some factor or other exceeded preflight levels. Thus, cardiac ejection decreased by a mean of 28% with LBNP before the flight and by 45% in the first inflight test.

It is quite likely that the results of tests made at the very beginning of the period of adaptation to weightlessness, when the compensatory and adaptive mechanisms were not yet fully formed, could differ substantially in nature and severity of reactions from the results of subsequent tests. Indeed, the crew visiting the orbital station showed a severe decrease in venous return of blood to the heart in the LBNP test on the 2d-3d day of weightlessness and, as a result, significant decrease in cardiac ejection, as well as changes in several phases of the cardiac cycle without adequate changes in HR, AP and other hemodynamic parameters.

Unlike the visiting expeditions, the reactions to the LBNP test of the main crew was less marked in the course of the mission, and it largely reflected the individual dynamics of adaptation to weightlessness. For example, the reaction to LBNP gradually approximated preflight findings in the CDR in the course of the flight (see Table 1). Here, we can apparently refer to stabilization of changes induced by LBNP and of virtually complete adaptation to weightlessness. At the same time, the reaction of the FLE to LBNP remained more marked in the course of the flight, as compared to preflight findings, and maximum changes were observed during the last inflight test. Interestingly enough, in both the last and preflight tests, he presented an inadequate vascular reaction to the induced redistribution of blood. The decrease in PWPR as well as UFS [expansion not known, probably typo] in relation to the levels that were proper for the given MV should be considered unfavorable signs.

Table 1. Circulatory parameters of CDR during LBNP test

Parameter	Preflight (mean data)		Inflight days										Postflight days			
			14		49		60		77		92		3		11	
	BG	LBNP	BG	LBNP	BG	LBNP	BG	LBNP	BG	LBNP	BG	LBNP	BG	LBNP	BG	LBNP
HR/min	69	80	67	84	64	79	65	72	72	75	67	78	74	83	71	82
MnAP, mm Hg	72	78	76	70	67	58	67	67	62	60	69	59	79	73	97	94
MAP, mm Hg	100	100	108	92	91	85	108	91	100	90	106	104	102	107	130	120
LsAP, mm Hg	122	117	131	115	107	105	120	105	110	101	117	110	123	126	150	150
SV, mℓ	126	87	95	42	92	70	107	—	111	59	147	82	102	93	119	100
MV, ℓ/min	8.6	6.7	6.4	3.6	5.9	4.9	6.9	—	8.0	4.3	9.8	5.3	7.5	7.7	8.5	8.1
PWPR, m/s	6.0	6.0	9.1	11.2	6.6	9.0	7.8	—	6.1	7.9	5.7	7.2	5.6	6.1	5.8	6.1
PEB, s	0.28	0.24	0.28	0.21	0.30	0.26	0.30	0.27	0.27	0.25	0.28	0.23	0.25	0.21	0.25	0.22

Key (here and in Table 2): BG--background

Table 2. Circulatory parameters of FLE during LBNP test

Parameter	Preflight (mean data)		Inflight days										Postflight days			
			11		49		60		77		92		3		11	
	BG	LBNP	BG	LBNP	BG	LBNP	BG	LBNP	BG	LBNP	BG	LBNP	BG	LBNP	BG	LBNP
HR/min	56	61	56	69	66	78	67	82	67	78	70	87	63	72	62	65
MnAP, mm Hg	64	65	54	58	58	52	72	68	63	60	58	56	[illegible]	78	77	77
MAP, mm Hg	88	92	84	93	78	82	90	90	83	85	86	78	96	94	98	90
LsAP, mm Hg	108	111	109	105	95	93	106	100	100	97	100	91	124	119	125	112
SV, mℓ	114	74	103	43	99	—	74	36	54	42	93	31	109	45	133	59
MV, ℓ/min	6.4	4.4	5.8	3.1	6.9	—	5.0	2.9	3.6	3.2	6.6	2.7	6.9	3.3	8.3	3.7
PWPR, m/s	5.8	6.4	8.5	9.3	7.0	—	7.0	9.1	9.7	8.9	6.7	10.3	5.8	7.8	5.1	6.1
PEB, s	0.30	0.25	0.30	0.22	0.32	0.21	0.29	0.20	0.27	0.20	0.27	0.17	0.26	0.20	0.28	0.23

This was also confirmed by subjective evaluation of the last inflight test, which was, on the whole, indicative of diminished tolerance of LBNP. Evidently, as the cosmonauts adapted to weightlessness there was stabilization of reactions of the cardiovascular system to LBNP, on a level that reflected individual endurance of the analogue of postural factors.

Apparently, the more marked changes with LBNP in the FLE during the flight are attributable not only to his individual distinctions, but inadequate scope of preventive measures. It is assumed by American researchers [4] that a marked decrease in cardiac output [ejection] with LBNP, which was observed in the FLE, could alter the efficiency of compensatory mechanisms of the cardiovascular system to such an extent that they are incapable of reacting adequately to the created load. The less shifting of blood to the top half of the body induced by weightlessness at rest, the better the LBNP test. The view is held that physical conditioning could prevent the shifting of blood in a cranial direction. For this reason, it may be assumed that the poor tolerance of the FLE of the functional test with LBNP is attributable to an insufficient volume of physical exercise. It should also be noted that the changes in a number of parameters of the FLE during LBNP were almost the same as with an orthostatic test, and even more marked in the last test.

According to the data of Soviet and American researchers, LBNP of -50 mm Hg may be considered an analogue of the orthostatic test with respect to physiological effects on the ground [5, 6]. However, in weightlessness this level may fluctuate substantially due to the dissimilar endurance of such factors. On the basis of the reaction of the FLE, it may be assumed that changes analogous to orthostatic reactions occurred in him with LBNP of -35 mm Hg. According to the results of American researchers [4], the same levels of LBNP are tolerated much worse in weightlessness than on earth, and they are subjectively equated by cosmonauts to greater rarefaction. For example, LBNP of -30 mm Hg is tolerated in space like -50 mm Hg on earth [4]. However, we believe that these correlations can only be valid for diminished orthostatic stability during the flight. In the case of retention of orthostatic stability during the flight, LBNP of -35 mm Hg is tolerated in space just as it is on the ground. It would be desirable to conduct this test in both the preflight and postflight periods to gain fuller and better understanding of the changes that occur in cardiovascular system with LBNP in weightlessness.

According to the nature of changes in the postflight LBNP tests, the impression is gained that the readaptation period was less successful for the FLE than CDR. The reduction of stroke and cardiac ejection of blood with LBNP reached maximum levels, which were recorded on the 14th and 92d flight days.

Thus, the functional test with LBNP confirmed its informativeness in determining the state of cosmonauts' circulatory system in the course of a long-term flight. The reactions of the cardiovascular system in both

crew members for the first 2 weeks were indicative of diminished tolerance of LBNP. At the subsequent stages of the flight, the reaction of the cardiovascular system to LBNP was close to normal in the CDR. In the FLE, the circulatory reaction to LBNP was more marked, which was indicative of diminished orthostatic stability.

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DYNAMICS OF DIASTOLIC PHASE STRUCTURE DURING A 140-DAY SPACE FLIGHT

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[Article by I. V. Alferova, A. D. Yegorov and A. P. Polyakova, submitted 12 Jun 79]

[English abstract from source]

The kinetocardiographic study of the diastolic structure demonstrated its consistent changes. In the first flight month they included an increased time of total diastole, filling and diastasis periods. Later these parameters shortened. The phase of isometric relaxation was reduced whereas that of rapid filling was enlarged throughout the flight. These changes seem to be associated with fluid redistribution, shift in the pressure gradient and enhancement of the sucking activity of the heart.

[Text] At the present time, no information is being reported about the dynamics of cardiac relaxation during space flights. At the same time, analysis of the phasic structure of the diastole (D) in weightlessness would make it possible to come closer to a more substantiated evaluation of cardiac function, including contractile function of the myocardium, since this function, in particular, is determined by presystolic distension of the myocardium. It is also important to comprehend the role and share of diastolic relaxation in adaptive hemodynamic reactions in weightlessness. The publications of recent times indicate that there is a possibility of change in circulation in the systemic and pulmonary systems [1, 2]. In particular, changes have been found in minute volume of circulation, increased pressure in the jugular vein and pulmonary artery [1], and there are indications of a reduction of the pressure gradient in the venous system [2], which could, of course, lead to a change in the role of the suction function of the heart in hemodynamics under weightless conditions.

In this work, we have tried to examine the dynamics of systolic p[illegible]ters (according to results of kinetocardiography) of the second main [illegible] the Salyut-6--Soyuz complex in the course of a 140-day space fli[illegible]

Methods

We examined the phasic structure of the diastole by the kinetocardiographic (KKG) method. Mechanical signals were converted by means of a piezoceramic sensor, the receiving part of which, in the form of rubber capsules (4×6 cm in size) filled with porolon [plastic], was placed in the region of the apex beat and fourth intercostal space on the right, on the parasternal line [3]. The KKG was recorded on Polynome-2M equipment at relative rest, and the data were transmitted to earth via telemetry channels. The studies were conducted 4 times before the flight, 16 times during the flight and twice in the postflight period.

In evaluating the KKG by the method described by L. V. Andreyev [4], we measured total duration of D, phases of isometric relaxation (IR and IR/D), of rapid (RF and RF/D) and slow (SF and SF/D) filling, and atrial systole. For the sake of convenience of presentation and to rule out random fluctuations, all of the parameters were averaged for each month.

Results and Discussion

There were two phases of changes in duration of total D, PN [expansion not furnished; pulsed filling?] and SF phase. Changes in the other parameters of D (IR, RF) were in the same direction throughout the flight. At first D of the left ventricle increased (in the 1st month of the flight), then decreased: the absolute values of total D decreased by 10-25% in the commander (CDR) and by 13-19% in the flight engineer (FLE); the relative values decreased by 7-14 and 3-11%, respectively. The CDR presented a tendency toward more marked changes toward the end of the flight (see Table). Duration of PN and SF phase increased substantially in the 1st month of the flight and to a lesser extent in the 2d month; thereafter it increased, and the decrease in these parameters progressed in the CDR constituting 22 and 40%, respectively by the end of the mission; there was a 17 and 19% decrease, respectively, in the FLE. The relative PN increased by 3-10% in both cosmonauts, and in some cases exceeded the preflight level.

The RF phase of the left ventricle was characterized by changes in different directions: it increased by 52-109% in the CDR and decreased by 15-25% in the FLE. The absolute and relative IR phases of the left ventricle decreased by 9-50% in both cosmonauts at different stages of the flight.

The changes in D parameters of the right ventricle were characterized by an increase in absolute and relative values of D by 24-38 and 11-12%, respectively, 24-47% increase in PN and 38-70% increase in SF during the first 2 months. Thereafter, these parameters began to decline, with the exception of absolute D and PN, which showed virtually no difference from preflight values. The SF phase was 18-79% increased in the CDR and 22-85% increased in the FLE throughout the flight. There was a decrease in absolute and relative values of the IR phase in the CDR, whereas they increased in the FLE.

Dynamics of mean values of main parameters of left and right ventricular diastole in the course of the 140-day flight

Parameter	CDR preflight (means)	CDR in flight, month		FLE preflight (means)	FLE in flight, month	
Left ventricle						
IR, ms	85	62	42—57	88	50	47—62
IR/D, %	17,9	11,9	10,1—15,6	17,2	9,0	11,5—15,6
PN, ms	390	460	300—340	410	500	340—380
PN/D, %	81,9	87,7	84,1—89,8	82,7	90,6	86,2—88,9
RF, ms	41	79	62—86	95	100	71—81
RF/D, %	8,7	15,2	17,2—21,5	19,4	18,5	16,5—19,1
SF, ms	295	330	180—260	250	340	от 200 до 240
Right ventricle						
IR, ms	46	31	36—48	41	41	45—64
IR/D, %	10,1	5,0	10,4—12,9	8,9	7,1	10,7—13,6
PN, ms	410	600	320—420	430	540	350—410
PN/D, %	—89,8	95,1	86,4—89,7	91,5	92,2	83,6—89,6
RF, ms	45	53	67—81	49	66	60—90
RF/D, %	9,7	8,7	17,1—21,4	10,7	11,1	15,6—19,4
SF, ms	300	510	190—290	310	430	220—260

Thus, the changes in the main parameters of right and left ventricular D were in the same direction during the flight in many instances.

According to current conceptions, the liquid media of the body are redistributed in weightlessness, and this leads (at least at the early stage) to an increase in venous return, elevation of pressure in the atria, as well as to an increase, as demonstrated during the flight, in stroke and minute volumes of blood. The increased force of cardiac contraction that occurred with this (shorter isometric contraction) could activate the mechanism responsible for diastolic relaxation [5], and together with the elevated pressure in the atria this probably causes shortening of IR phase. The initial increase in duration of PN can be interpreted as the result of increased influx of blood and filling of the ventricles during D.

The change in structure of D, which developed in the 2d month of the flight, reflects adaptation of the circulatory system to function during long-term weightlessness. The redistribution of body fluids and effects it induces occur immediately after the body is submitted to weightlessness and thereafter, being compensated in part by an increase in deposition and removal of fluid from the body (in particular by the Henry-Gauer mechanism), they persist throughout the flight. This was indicated by the persistent tendency toward increased minute volume of circulation throughout the 140-day mission, increase of parameters of pulsed delivery of blood to the head for the duration of the flight (over 3 months),

as well as the shift of the mass center in a cranial direction, which persisted in astronauts during the 84-day mission on the Skylab program, with concurrent decrease in leg volume by 2 liters [2].

The possibility cannot be ruled out that the decrease in activity of peripheral "muscular hearts" (due to shortage of muscular exercise and decrease in postural and tonic function of muscles in weightlessness), which cause blood to move from arteries through capillaries of skeletal muscles into veins, thereby alleviating the work of the heart [7], plays a certain part in the hemodynamic changes occurring during space flights.

In the opinion of American researchers, a constant pressure, which equals central venous pressure, is established in the entire venous system as a result of redistribution of blood. The decrease in pressure gradient of the venous system in systemic circulation and in the system of the pulmonary veins and left atrium (increased deposition of blood in the cardiopulmonary region), as well as the decrease in activity of "intramuscular peripheral hearts,"* apparently cause an increase in the role of active D (suction function of the heart) in hemodynamics. For this reason, there is a change in structure of D, in the former of shortening of IR period and SF phase, with concurrent extension of RF phase, which provides for active filling by means of the suction function of the heart.

Thus, the adaptive reactions directed toward providing for efficient hemodynamics generally amount to an increase in ouput function of the heart *longer period of ejection and RF phase) at the expense of hemodynamically inefficient isometric phases of its function and decrease in duration of physiological rest of the myocardium.

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RESULTS OF INFLIGHT ELECTROCARDIOGRAPHIC STUDIES OF SALYUT-5 CREW

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[Article by V. A. Degtyarev, V. S. Bednenko, V. K. Gabyshev, V. A. Sapozhnikov and V. P. Sidorov, submitted 24 May 78]

[English abstract from source]

In Salyut-5 crewmembers, electrocardiograms were recorded in 12 standard and D - S leads. No marked changes in bioelectric properties of the myocardium were detected. However, during the second part of the mission B. V. Volynov and V. M. Zholobov showed changes in the terminal portion of the ventricular complex in the left sternal leads. It is presumed that they were induced by repolarization anomalies due to neurohormonal effects on myocardial metabolism. Members of the second crew did not exhibit similar electrocardiographic changes.

[Text] The electrocardiographic studies conducted aboard the Salyut and Skylab manned orbital stations (MOS) failed to demonstrate appreciable EKG signs of impairment of bioelectrical properties of the myocardium [1-3]. Yet disturbances of cardiac function were noted previously during space flights. Thus, cardiac arrhythmia developed in two crew members of the Apollo 15 spacecraft [4]. For this reason, a 2-week study was made on the crew after this mission, using clinostatic hypodynamia, with the same trace elements in the diet as during the flight. No functional cardiac disturbances were demonstrated in the crew during this study, so that it was possible to rule out, with some degree of probability, disturbances of fluid-electrolyte balance as the chief cause of arrhythmia. Nevertheless, a microinfarction developed in one of the astronauts 1 year after the flight [5], which was apparently not the direct consequence of the adverse space flight factors. However, we cannot rule out the possibility that the space flight conditions were instrumental in manifestation of latent heart disease.

The changes demonstrated on the EKG of Soviet cosmonauts were related primarily to individual functional distinctions of the myocardium and regulation of cardiac function. These changes (single extrasystoles, sinus arrhythmia, bradycardia) were noted both before and during the flight. We submit here the results of a complete electrocardiographic study of the

crew aboard the Salyut-5 manned orbital station, which was conducted at different stages of the flight.

Methods

In the course of ongoing medical monitoring, the EKG was recorded in the DS lead, and in 12 leads (I, II, III, aVR, aVF, CR_{1-6}) in the comprehensive studies using Polynome-2M equipment. The signal was picked up in analog form by ground-based reading centers and recorded on paper tape. The interrogation frequency constituted 200 pulses/s and tape feed rate was 70 mm/s. Measurement was made of time parameters of the EKG, amplitude of waves, magnitude and direction of vector of the ventricular gradient. The rhythm was analyzed on the EKG with the DS lead (4-8-min tracings).

Results and Discussion

The correct sinus rhythm was retained by all cosmonauts during the mission. Figure 1 illustrates the dynamics of heart rate (HR) during the flight. HR reached preflight levels by the end of the 1st week of the flight in the commander of the first crew (CDR-1) and by the end of the 3d week in the first crew's flight engineer (FLE-1). Thereafter, HR changed by 10-15% of preflight values (in the direction of both increase and decrease) in CDR-1, whereas in the FLE-1 it periodically increased by 10-20%. The intensity of work during the second expedition and the first 20 days of the first expedition was approximately the same; however, the HR remained 15-20% higher than preflight values throughout the mission in the commander and flight engineer of the second expedition (CDR-2 and FLE-2, respectively).

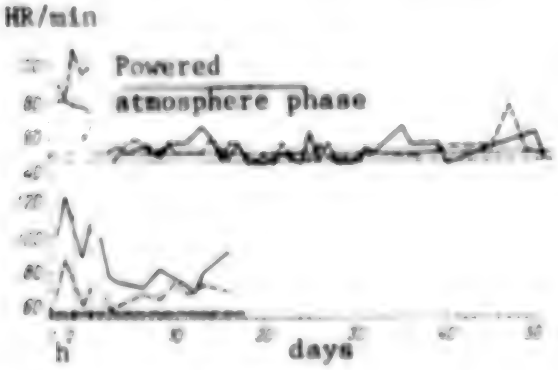

Figure 1.
HR dynamics in flight for CDR-1 and FLE-1 (top curves), CDR-2 and FLE-2 (bottom curves). The straight lines show mean preflight level, solid line, HR for the CDR and dash line, for the FLE

In evaluating the nature of HR changes during the flight in the crew of Salyut-5 MOS, it must be noted that the causes of the observed changes could vary. A faster or slower HR is a nonspecific reaction of the cardiovascular system to many environmental factors. One of the most likely factors that could lead to unstable HR parameters at rest among the crew of Salyut-5 MOS was the marked nervous and emotional tension, which was related to the large work load aboard this MOS. In addition, the circadian biorhythms interacted constantly with the work rhythms during the shortened "onboard" days. All this, along with other changes in body functions under the influence of space flight factors, could have been the cause of considerable variation of HR when recorded at relative rest.

All of the crew members presented respiratory arrhythmia, and it was more marked against the background of bradycardia in the CDR-1 and FLE-1. As in the preflight period, FLE-1 and FLE-2 presented isolated atrial extrasystoles. In this regard, it must be noted that the FLE-2 had previously participated in tests of life support systems in a MOS mockup. In the course of those tests, he presented extrasystoles more often than during the actual flight. The time of atrioventricular conduction and duration of QRS complex remained at preflight levels in the crew of the second expedition throughout the mission. Starting in the 2d 10-day period of the mission, the CDR-1 and FLE-1 presented an increase in time of atrioventricular conduction, as well as transient increase in ventricular depolarization time (Figure 2). Against the background of sinus bradycardia, which was typical of both cosmonauts of the first expedition, the slower conduction could be attributed to intensification of influences of the parasympathetic component of regulation of cardiac function [6, 7]. According to the data of Smith et al., an increase in time of atrioventricular conduction was also noted in the crew of the Skylab MOS . However, in the crew of the second expedition of the Salyut-4 MOS the duration of the P-Q interval decreased with concurrent increase in duration of the QRS complex [1]. Thus far, the cause of intensification of vagal influences, which was noted during long-term space flights, has not been definitively determined. Duration of the Q-T interval did not exceed proper levels in any of the crew members of the Salyut-5 MOS. The direction and magnitude of the ventricular gradient vector in the frontal plane did not exceed the normal range.

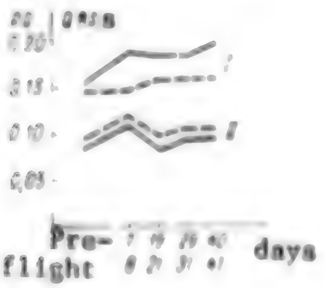

Figure 2.
Inflight atrioventricular (I) and intraventircular II) conduction time (s) for CDR-1 (solid lines) and FLE-1 (dash lines). X-axis, day of examination of CDR-1 (top) and FLE-1 (bottom)

Figure 3.
EKG of CDR-1 on the 7th (left) and 29th (right) days of the flight

By the end of the 1st month of the mission, the CDR-1 developed changes in the terminal part of the ventricular complex, in the left thoracic leads (CR_{4-6}). In these leads, the T wave acquired a symmetrical form, and it was flattened (Figure 3). Thereafter, these changes became more marked. The ST segment dropped by 1-1.5 mm, and its slope in relation to the isoline disappeared. By the end of the mission, analogous tendencies of

change in the terminal part of the ventricular complex began to be observed in the FLE-1 as well. These phenomena underwent rapid regression after landing. The EKG of the CDR-1 reverted to normal on the 3d postlanding day, and somewhat later the same applied to the FLE-1. No such EKG changes were observed in the members of the second crew of the Salyut-5 MOS.

In all likelihood, the demonstrated changes cannot be interpreted as positional (which had not been ruled out previously [1]), since the shape of the T wave and decline of the ST segment were more indicative of changes in bioelectrical properties of the myocardium manifested at the repolarization phase. At present, extensive material has been accumulated in the literature, which pertains to neurohumoral influences on metabolic processes in the myocardium [7-12]. It was reported that a number of myocardial metabolic disturbances [13], which are unrelated to coronary insufficiency, lead to deformity of the terminal segment of the ventricular EKG complex. These changes consist of several stages, ranging from decline to inversion of the T wave. Such phenomena are found in overtrained athletes and individuals with clinical manifestations of emotional instability. Unfortunately, they are seldom detected at the early stage of development, so that insufficient information has been obtained about their relation to duration and force of effects of environmental factors. Some authors [14] believe that the changes in the terminal part of the ventricular complex could be related to diminished tonus of the sympathetic nervous system and corresponding increase in parasympathetic influences, which leads to changes in the repolarization process. If we consider that, in the case, several other signs were observed that were indicative of increased tonus of the vagus, the demonstrated changes in the terminal part of the ventricular complex could be classified as so-called neurodystrophy [11]. Moreover, after landing, these changes disappeared rapidly, against the background of general stress and increased tonus of the sympathetic system, in the CDR-1 and FLE-1, which could also be indicative of their functional, neurogenic nature.

Thus, changes in the terminal portion of the ventricular complex in the left thoracic leads, which were observed in members of the first crew of the Salyut-5 MOS, can be most probably attributed to metabolic disturbances related to a change in neurohumoral regulation in weightlessness, against the background of a large work load. In our opinion, it would be much easier to interpret the electrocardiographic changes if appropriate inflight biochemical tests were made.

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FUNCTIONAL ASYMMETRY OF OPERATOR PERFORMANCE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 5, 1980 pp 39-42

[Article by A. G. Fedoruk and T. A. Dobrokhotova, submitted 17 Aug 79]

[English abstract from source]

The relationship between the level of operator's activity and functional asymmetry of hands, feet, eyes and ears has been established. The level of operator's activity is increased due to a well expressed right-handed asymmetry of hands, eyes and ears with feet asymmetry being of less importance

[Text] The study of functional symmetries and asymmetries in man is of paramount applied importance to optimization of working conditions and efficiency, as well as vocational guidance of students in the occupational screening system.

In this work, the use of the teaching on functional asymmetry of man is discussed for the above purposes on the example of operator performance.

Methods

A study was made of 200 men ranging in age from 20 to 35 years engaged in operator occupations. Before learning this occupation and prior to the start of their professional work, these individuals had undergone strict screening and thorough physical examination, in which, however, the nature of functional symmetry and asymmetry in each of them was not taken into consideration. All of the subjects were essentially healthy.

Operator work of the type we examined requires maximum concentration and rapid shifting of attention, flawless reading, remembering and interpreting display readings in the operator's field of vision, as well as working with numerous switches and levers. The operator had to accurately perceive and correctly evaluate situations close to emergencies or accidents; he had to make decisions rapidly and act rapidly within a strictly limited time, adequately perceive the time and space parameters of his location and the controlled equipment, as well as extraneous objects in relation to it.

Our systematization was based on the quality of professional performance. Of the 3 groups we formed, the first (89 men) consisted of subjects who performed work with a "good" rating; the second (67 people) were operators whose work was rated as satisfactory, and the third (44 men) consisted of individuals who had been involved in an accident [emergency] or were unable to prevent accident situations that arose for technical reasons.

In order to determine the extent to which (and how) individual motor and sensory asymmetries affect the quality of operator performance and which combinations of functional asymmetries are associated with optimum performance, we examined the coefficient of dominance of the right hand, motor activity of the legs, presence or absence of dominant eye according to aiming skill and coefficient of perception of verbal signals on the right.

The coefficient of dominance of the right hand is de[termined] with the following formula:

$$K_r = \frac{\Sigma_r - \Sigma_l}{\Sigma_r + \Sigma_l + \Sigma_0} \cdot 100\%,$$

where Σ_r is the total number of operations in which the right hand was dominant, Σ_l is the total number of procedures in which the left was dominant and Σ_0 is the total number of operations in which dominance of neither hand was demonstrated. A value of K_r in excess of +15% was rated as dominance of the right hand (right-handedness) whereas a value below -15% was rated as dominance of the left hand (left-handedness). Values lying between +15 and -15% were considered as indicators of equality, symmetry of the hands, or ambidexterity.

We used the following procedures to determine the coefficient of right-handedness. There was mandatory consideration of whether there were left-handed and ambidextrous relatives of the subject, with which hand he performs actions better (throws ball, holds tool, winds a watch, brushes his teeth, lights a match), with which hand he starts a task involving manipulations, which hand is favored in gesticulating and which presents a marked venous network on the back of the hand. We measured the strength of each hand three times using a manual dynamometer, and we calculated the mean parameter. A difference of less than 2 kg was interpreted as an indication of equality of the hands in force, and with a difference in strength of more than 2 kg, the stronger hand was considered dominant. We measured the length of the arm in dropped position, from the acromial process of the scapula to the tip of the third finger. A difference of up to 0.2 cm was interpreted as equality of arms, and one that was over 0.2 cm longer than the other was considered dominant. A micrometer was used to measure the width of the nail bed of the thumb; absence of difference was interpreted as equality of hands, whereas the hand that had a wider nail bed than the other was considered dominant. We timed the process of unscrewing and screwing 25 bolts with the right and

left hands; with a difference of up to 30 s, the hands were considered equal, whereas the hand with which this task was performed more than 30 s faster was considered dominant. We noted dominance of elements in squares and circles traced simultaneously with the right and left hands without visual control; the hand that traced the most complete figures was considered dominant. We recorded deviations from a paper target, 20 cm in diameter, located at extended arm's length, in writing 10 points in with a pencil, with the right and left hands; the hand whose deviation was less than 10 cm was considered dominant. The subjects also did the following tests: clasping both hands together (the thumb of the dominant hand is on top) and crossing the arms on the chest (the palm of the dominant hand is placed over the arm of the nondominant hand). The tests we used as a whole enabled us to determine which hand was stronger, more dexterous, as well as the reaction speed and accuracy of motor coordination or equality of the hands according to the same characteristics.

To determine which leg was dominant, we took into consideration self-appraisals (which foot was used to push off for a jump) and the deviations when walking, in light-proof glasses, toward a target (sheet of white paper on the floor) at a distance of 5 m; the foot on the opposite side of the deviation, determined by the fact that longer steps were made with the dominant foot, was considered dominant. In calculating the mean dominance of feet in the different groups, we arbitrarily ascribed to dominance of the right (+1) or left (-1) foot the digit 1, and to absence of dominance 0.

In addition to considering the subjects' self-appraisal, we used the following test to determine the dominant (according to aiming skill) eye: We cut out a hole (1×1 cm) in a sheet of thick paper (5×10 cm). Holding the opening in front of the eyes, at a distance of 30-40 cm, the subject had to fix on a small object located 2-3 m away, then alternately close the right and left eye. If the object shifted when one eye or the other was shut, the eyes were rated as equal in aiming capacity. The eye was considered dominant if there was no shifting of the target object when it was closed. When calculating the mean value of eye asymmetry according to aiming capacity for each group, we arbitrarily assigned the numeral 1 to the presence of a dominant eye, +1 referring to the right eye and -1 to the left, with 0 referring to absence of a dominant eye.

The coefficient or effect of hearing was determined by the method of dichotic listening to words with concurrent presentation thereof on the right and left by means of a stereophonic tape recorder. This coefficient was calculated with the following formula:

$$K_h = \frac{\Sigma r - \Sigma l}{\Sigma_r + \Sigma_l} \cdot 100\%,$$

where Σ_r is the total number of correctly repeated words presented on the right and Σ_l is the total number of correctly repeated words presented on the left. A positive value of K_h shows dominance of the left cerebral hemisphere for speech and a negative one, dominance of the right hemisphere.

Results and Discussion

Table 1 lists the results of testing all 200 operators.

Table 1. Correlation between functional asymmetries and symmetries (%)

Asymmetry--symmetry		Hands	Feet	Vision	Hearing
Asymmetry	right-sided	86.0	49.5	68.5	59.0
	left-sided	4.5	47.5	25.5	8.0
Symmetry		9.5	3.0	8.0	33.0

Table 2. Correlation between functional asymmetries and symmetries in different groups (%)

Asymmetry and symmetry		Group											
		1				2				3			
		hands	feet	vision	hearing	hands	feet	vision	hearing	hands	feet	vision	hearing
Assymetry	right-sided	97.7	44.9	87.6	96.6	83.6	56.7	62.7	35.8	65.9	43.2	38.6	18.2
	left-sided	0	52.8	11.2	0	4.5	38.8	31.3	3.0	13.6	54.5	36.4	29.5
Symmetry		2.3	2.3	1.2	3.4	11.9	4.5	6.0	61.2	20.5	2.3	25.0	52.3

Table 1 shows that asymmetry dominated drastically over symmetry for all of the tested parameters. We can call attention to the smaller share of left-handed and ambidextrous subjects, as compared to figures cited in the literature, which range from 10 to 30% [1-4].

Of greatest interest was the correlation between various forms of asymmetries and symmetries in different groups, which is shown in Table 2.

Dominance of asymmetry (right-sided) over symmetry was more marked in the first group of subjects. There were no individuals with left-sided asymmetry referable to motor activity of the hands and hearing in the first group. The tendency toward right-sided asymmetry was less marked in the second group than the first. The second group had subjects with left-sided asymmetry of the hands and hearing, which was not present in the first group, and with regard to vision it increased by almost 3 times, as compared to the first. There was a very mild tendency toward dominance

of the right foot. The share of symmetry was higher in the second group than the first with regard to all parameters. It increased particularly in the area of hearing; the second group also differed from the first in that the combinations of various asymmetries were heterogeneous and much more variable.

Right-sided asymmetry was even less marked in the third group, and left-sided asymmetry was dominant in hearing. There was an increase in share of symmetry referable to motor activity of the hands and vision. As compared to the second group, there were three times more subjects with negative K_r, i.e., left-handed people. As was the case for the second group, the third group failed to demonstrate any definite pattern of asymmetry-symmetry combinations for the tested parameters. But it is remarkable that there were subjects in this group who presented left-sided asymmetry.

We calculated the mean value of the tested parameters for graphic presentation of differences in profile and magnitude of functional asymmetry of operators in different groups (Table 3).

Table 3. Magnitude of functional asymmetry in different groups

Type of asymmetry	Group		
	1	2	3
Motor activity of hands	63,0±2,0	41,8±3,4	23,9±4,3
Motor activity of feet	−0,08±0,1	0,2±0,1	−0,1±0,1
Vision	0,8±0,06	0,3±0,1	0,02±0,1
Hearing	40,9±1,7	11,4±2,1	−4,9±2,7

Table 3 shows that the mean K_r is highest in the first group, lower in the second and third groups. In the first group it ranges from 100% (in 2 subjects) to 11%, in the second from 91 to -44% and in the third from 69 to 50% (in 2 subjects). The wide scatter of individual values for K_r is indicative of different degrees of right- and left-handedness. There was overt prevalence of strongly right-handed individuals in the first group: K_r was in excess of 50% in 73 (82%) out of 89 subjects, whereas K_r was demonstrable in 32 (48%) out of 67 cases in the second group and only 8 (18%) out of 44 in the third. At the same time, 2 operators in the third group presented marked left-handedness, which was absent from the first and second groups, with K_r of -50%.

There were also obvious differences between the groups in degree and profile of hearing asymmetry. K_h ranged from 92 to 10% in the first group of subjects, 57 to -36% in the second and 26 to -50% in the third group. K_h was above 50% in 28 (31%) out of 89 subjects in the first group. This held true for only 2 (3%) of the men in the second group. Not a single operator in the third group had a K_h of over 26%.

There were also overt differences between groups with regard to extent of asymmetry of the eyes (vision) according to aiming capacity.

We failed to demonstrate a similar pattern with regard to the feet, as asymmetry diminished from the first to third groups. Symmetry and asymmetry of foot function appeared to be the least significant to operator performance.

Thus, best performance by the tested operators was always combined, in the first place, with maximum functional asymmetries and minimum share of symmetries and, in the second place, with marked prevalence of right-sided asymmetries over left-sided ones with regard to all parameters (except foot activity).

Poorest performance of professional work (for example, inability to avoid accidents as demonstrated in stress situations, in spite of good general training and skill in each specific task) was noted in the third group of operators, against the background of much less marked asymmetries and increased share of symmetry, as well as less tendency toward right-sided asymmetries.

The second group of operators, who performed their work satisfactorily, occupied an intermediate position with respect to the mean values of functional asymmetries.

Of greatest interest is the drastic difference in degree and profile of functional asymmetries in the first and third groups. It indicates that the combination of motor and sensory asymmetries that is associated with dominance of the left cerebral hemisphere is optimal for operator performance. For example, the profile and degree of functional asymmetries inherent in the minority of mankind that is not right-handed are not advantageous [1, 2, 5, 6]. Here, the placement of display devices, switches and levers in the operator's work space acquires the utmost importance. The lay-out takes into consideration the functional organization of only the right-handed majority of people. Consequently, the working conditions for operators are convenient for right-handed people and do not conform with the natural inclinations of those who are not, although there are no recommendations concerning the profile and degree of functional organization of candidates in the existing rules for professional screening.

The obtained data show convincingly that the degree of right-sided asymmetries referable to motor activity of the hands, vision and hearing are instrumental in efficient and accident-free operator performance. Left-sided asymmetries of the same parameters are demonstrable in operators with poorer quality of professional performance. These data justify the need to take into consideration the profile and degree of individual functional asymmetries and symmetries when analyzing the causes of operator errors, as well as solving problems of professional screening.

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EFFECT OF SOME FACTORS THAT SIMULATE SPACE FLIGHTS ON BLOOD PLASMA LEVELS OF FREE AND PROTEIN-BOUND 11-HYDROXYCORTICOSTEROIDS

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[Article by S. S. Kalandarov, V.P. Bychkov, A. S. Ushakov and G. I. Proskurova, submitted 4 Jan 79]

[English abstract from source]

The effect of spaceflight simulation factors (ascent to an altitude of 8,000 m, anticipation of centrifugation, psychological test, hypokinesia, and enclosure in an altitude chamber) on the content of free and protein-bound 11-hydroxycorticosteroids in plasma was studied. This exposure produced changes in the total and fractional content of the hormones. The changes depended on the simulation factor, duration of its action, and functional status of test subjects.

[Text] As a rule, the effects of various extreme factors (including space flight factors) on the function of the adrenal cortex are studied by means of assaying total corticosteroid metabolite content of urine or blood plasma [1-4]. However, according to current beliefs, corticosteroid content of plasma is not a criterion of their biological activity, since it depends on the degree of binding of hormones with transcortin, a specific plasma protein [5].

The physiological significance of formation of protein-steroid complexes apparently consists of reversible inactivation of hormones, protection thereof against further conversions, creation of a mobile reserve. On the other hand, transcortin is apparently involved in the transport of corticosteroids, affecting the rate of their passage into tissues, nature of tissular effect and metabolism in the liver [6, 7].

Since transcortin-bound corticoids have no activity [8], the biological action inherent in these hormones is performed by their free form. One should assess adrenocortical function, as well as levels of corticosteroid metabolites in blood plasma and urine, according to the change in proportion between free and protein-bound forms of corticosteroids. In this way, it will apparently be possible to determine the true nature of effects of space flight factors on adrenocortical function, as well as to

demonstrate changes in "capacity" of transcortin. An increase in "capacity" of transcortin is interpreted as a manifestation of hypercorticoidism of extra-adrenal origin [9].

In this work, we studied the effects of a number of factors that simulate space flight conditions on the proportion of various forms of steroids in human blood plasma.

Methods

A total of 43 essentially healthy men ranging in age from 22 to 36 years participated in these tests; they were divided into eight groups. The first group consisted of 5 men submitted to simulated ascent to 8000 m in a pressure chamber and expectation of G forces on a centrifuge. This group also performed a psychological test for which very limited time was allowed. The second group consisted of five men submitted to the same factors against the background of intake of food supplements (FS). The third group (7 men) performed graded physical exercise and mental work within very limited time, with intake of FS. Vitamins (ascorbic acid, undevit [multivitamin product with calcium pantothenate], B_{15}), minerals (potassium, phosphorus, calcium, magnesium, chlorine), glucose and phosphatide concentrate. The fourth group consisted of six men who maintained bed rest, the head of the bed elevated by +6°. The foot of the bed was dropped to -2° and -6° for subjects in the fifth and sixth groups (6 men in each), respectively.

The individuals in the seventh group (4 men) were submitted to the combined effect of high carbon dioxide concentration (to 3%) and low ambient temperature (to +16°C) in the pressure chamber; the eighth group (4 men) were submitted to high concentration of carbon dioxide (to 3%), temperature (to +35°C) and relative air humidity (to 90%).

The subjects were given a diet made up of canned foods that were balanced with regard to the main nutrients. The caloric value of the diet constituted about 3000 kcal.

We used the method of gel filtration [10] as modifed by L. V. Pavlikhina et al. [11], with fine-grain sephadex U-50, to separate free and protein-bound corticosteroids of plasma. A quantitative assay was made of total and fractions of 11-hydroxycorticosteroids (11-HCS) by the fluorimetric method [12] as modified by Yu. A. Pankov and I. Ya. Usvatova [13].

Results and Discussion

There was some decline of level of free 11-HCS in plasma (from 1.3 to 0.9 μg%, by 31%) in the 1st group of subjects (Table 1) after simulation of ascent in the pressure chamber. There was also a tendency toward increase in the bound form of hormones in plasma (from 15.5 to 16.3 μg%). When anticipating gravitational accelerations on the centrifuge, we observed some elevation of both the free fraction (to 1.7 μg%) and protein-

bound 11-HCS (to 17.2 μg%). Performance of the psychological test was associated with decline of all forms of hormones at all tested times.

Table 1. Protein-bound and free 11-HCS levels (μg%) in blood plasma of 1st-3d groups of subjects

Group	Time of examination	11-HCS					
		total content		protein-bound		free	
		before	after	bef.	after	bef.	after
1	Background	16.7±1.1	—	15.5±0.9	—	1.3±0.3	—
	"Ascent" in pressure chamb.	16.8±1.2	17.2±0.94	15.4±0.9	16.3±1.06	1.4±0.29	0.9±0.[illegible]
	Anticipation of centrifuge	18.9±0.72	18.9±0.72	17.2±0.0	17.2±0.0	1.7±0.72	1.7±0.[illegible]
	Psychological test	15.4±0.57	14.3±0.5	15.0±0.7	13.7±0.26	0.4±0.2[illegible]	0.6±0.[illegible]
2	Background	13.8±1.5	—	12.6±0.9	—	1.2±0.9	—
	"Ascent"	12.7±0.8	12.1±0.9	11.9±0.7	11.1±0.9	0.7±0.04	1.0±0.5
	Anticipation of centrif.	11.5±1.1	13.7±1.8	11.0±0.7	12.3±0.7	0.6±0.03	1.4±0.[illegible]
	Psychological test	24.6±1.2	—	22.0±1.7	—	2.6±0.5	—
3	Background	12.7±0.06	11.7±1.0	12.3±0.6	10.7±1.4	0.4±0.07	1.0±0.0
	Exercise	—	16.7±1.44	—	15.0±1.4	—	1.7±0.45
	Background + FS	—	22.3±1.6	—	20.5±1.96	—	1.8±0.7
	Exercise + FS	—	21.4±1.6	—	18.8±2.0	—	2.6±0.6

These factors did not have an effect on the second group of subjects who took FS: 11-HCS and fractions thereof remained unchanged in blood plasma.

Table 1 also shows that there was a decline of both the free fraction (from 2.6 to 1.7 μg%, by 35%) and protein-bound form (from 22.0 to 15.0 μg%, by 32%) in the third group under the influence of the combination of exercise and mental work. Concurrently, there was a decline of overall hormone level in blood. Thereafter (with intake of FS), there was recovery of free 11-HCS with concurrent increase in total 11-HCS content of plasma.

The data listed in Table 2 indicate that there was a decline in level of protein-bound form of 11-HCS in plasma in the 4th group of subjects, on the 26th day of the study. There were no appreciable changes in this parameter in the 5th and 6th groups. However, they presented a low level of free, biologically active 11-HCS. During bed rest, there was a decrease in reaction of the adrenohypophyseal system to administration of 40 units of ACTH (see Table 2) in the 6th group, as compared to the 4th and 5th. There was negligible change in protein-bound and free fraction after administration of ACTH in the 6th group. Reactivity of the adrenohypophyseal system remained rather high in the 4th and 5th groups throughout the period of the study. This was indicated by the high concentration of

protein-bound and free 11-HCS in blood plasma after giving ACTH. In the course of rehabilitation measures, the subjects in the sixth group failed to demonstrate recovery of the studied parameters. Thus, the concentration of protein-bound 11-HCS in blood plasma remained low after giving ACTH, while the level of free 11-HCS was slightly above background levels.

Table 2. Protein-bound and free 11-HCS levels (μg%) in blood plasma of 4th-6th groups of subjects

Group	Time	11-HCS					
		total content		protein-bound		free	
		before ACTH	after ACTH	bef. ACTH	after ACTH	bef. ACTH	after ACTH
4	Background	12.9±1.45	17.1±1.16	10.5±1.20	13.3±1.07	2.4±0.67	3.8±0.76
	26th day of hypokinesia	9.[illegible]±0.21	18.[illegible]	[illegible]±0.21	11.2±0.[illegible]	0.90±0.21	[illegible]
	9th day of recovery	10.3±1.15	14.[illegible]	9.1±1.[illegible]	10.9±1.[illegible]	1.2±0.21	[illegible]
5	Background	12.[illegible]±1.86	17.1±1.62	10.1±0.[illegible]0	12.5±1.[illegible]	2.5±0.77	4.5±0.[illegible]
	26th day of hypokinesia	12.7±0.72	20.2±1.80	11.6±0.70	18.9±1.80	1.2±0.21	4.3±0.61
	9th day of recovery	12.8±0.98	17.8±1.30	10.8±0.75	13.4±1.06	2.0±0.28	4.1±1.26
6	Background	9.1±0.83	15.[illegible]±1.19	8.1±0.79	12.3±1.20	1.3±0.21	3.7±0.[illegible]
	26th day of hypokinesia	10.3±0.96	15.[illegible]±1.11	9.5±0.92	13.3±1.08	0.8±0.20	1.[illegible]±0.28
	9th day of recovery	10.1±0.21	12.9±1.07	8.7±0.15	8.6±1.21	1.4±0.21	4.3±0.63

In the 7th group of subjects (Table 3), there was an increase in free 11-HCS of blood plasma to 3.3 μg% (background 2.3 μg%) under the influence of the combination of high CO_2 concentration and low temperature. There was a tendency toward decrease in the protein-bound form (from 23.3 to 16.5 μg%). Subsequently (7th day) there was a decrease in free 11-HCS with concurrent increase in bound fraction of 11-HCS. In the aftereffect period, total 11-HCS did not differ from baseline values. In the 8th group, there was a decrease in total hormones and fractions thereof on the 2d day of the study, whereas on the 7th day there was, on the contrary, an increase in free form of 11-HCS. We demonstrated a tendency toward decline of the level of the protein-bound form of 11-HCS (to 15.0 μg%, versus 19.1 μg% in the background). The amount of 11-HCS and fractions thereof was diminished in this group in the recovery period.

These studies revealed that, along with changes in total level of these hormones, there were also changes in fractions thereof under the influence of a number of factors inherent in space flights. Thus, there was a decrease in concentration of corticosteroids and fractions thereof during mental and physical work. Analogous changes were observed by A. A. Viru [14] and A. Ya. Soosaar [15]. Evidently, these factors are involved in

"utilization" of corticosteroids by various tissues, which leads to a decrease in their concentration in blood.

Table 3. Protein-bound and free 11-HCS levels (μg%) in blood plasma of 7th and 8th groups of subjects

Group	Time	11-HCS		
		total content	protein-bound	free
7	Background 2d day of exposure 7th day of exposure Recovery period	26.2±3.55 20.1±1.06 20.9±0.95 24.1±1.31	23.9±3.3 16.5±0.82 19.8±0.67 22.4±1.9	2.3±0.50 3±0.53 1.0±0.04 1.7±0.6
8	Background 2d day of exposure 7th day of exposure Recovery period	22.0±2.63 19.7±0.95 17.8±2.93 15.9±1.69	19.1±2.0 18.2±0.8 15.0±2.1 14.4±2.03	1.3±0.95 1.5±0.6 2.5±0.97 1.4±0.5

Intake of food supplements creates a mobile reserve, as a result of which there is apparently retention of corticosteroids that "are not utilized" by tissues, and their concentration remains normal in blood. Under hypokinetic conditions, various reactions were observed to administration of ACTH, depending on the position of the body, and they were referable to both 11-HCS fractions and reactivity of the adrenohypophyseal system. This is related to "switching" of the mechanisms of hormonal regulation to a lower level of activity, which is evidently a manifestation of the body's adaptive reaction to these conditions [16]. The combined effect of high carbon dioxide level and low temperature caused an increase in free 11-HCS. Protein-bound and total 11-HCS levels remained low. Analogous results were obtained by Knigge et al. [17] under the prolonged effect of cold.

It should be noted that the nature of the demonstrated changes was related both to the type of factor and duration of exposure to it, and the functional state of the body.

These studies also confirmed the desirability of examining free and protein-bound 11-HCS levels in blood plasma, along with assays of total 11-HCS, which provides fuller information about adrenocortical function when the body is exposed to space flight factors.

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RENAL FUNCTION AND GLUCOCORTICOID ACTIVITY OF THE ADRENAL CORTEX DURING IMMERSION

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[Article by I. S. Balakhovskiy and V. B. Noskov, submitted 18 Oct 79]

[English abstract from source]

The paper presents the study of renal and adrenal function in six normal men during and after 3-day water immersion used as weightlessness simulation. The renal excretion of fluid, basic electrolytes, creatinine and total 17-hydroxycorticosteroids (17-HOCS) for 24 hours and following a provocative water-load test (20 ml/kg) was measured. During the first post-immersion day diuresis increased by 77 %, excretion of sodium by 42 %, 17-HOCS by 43 % and creatinine by 34 % as compared to the pre-immersion level. Potassium excretion remained essentially unchanged. The circadian rhythm of excretion of the above substances was normal: at night the excretion decreased and in the morning increased noticeably. The study of renal function and adrenal activity was carried out 56 hours after the beginning of water immersion, using a provocative water-load test. Water excretory and osmoregulatory functions of kidneys, and glucocorticoid activity of adrenals remained normal. These data give evidence that during a 60 hour exposure to water immersion no functional hypocorticism develops.

[Text] There is some increase in blood urea of cosmonauts during space flights. After the missions, there is usually no marked increase in 24-h excretion of 17-hydroxycorticosteroids in urine; however, fluid retention and natriuresis were often demonstrated during functional tests with a water load [1-3]. Evidently, this can be attributed to a decrease in functional activity of the adrenal cortex, and this enabled us to expound a relevant hypothesis [4].

In this work, we tried to reproduce the above changes and check the above hypothesis using a widely used model of the physiological effects of weightlessness, immersion in water.

Methods

We made a study of 6 healthy men ranging in age from 19 to 21 years, who spent 60 h in a tub of water, submerged on a cot to the neck level. The temperature was kept at 34±1°C. The subjects were on a diet of natural products. A strict record was kept of food and fluid intake. We

collected each batch of urine, measured its volume and assayed sodium and potassium (by the method of flame photometry), 17-HCS [hydroxycorticosteroids] (by a modification of the Silber-Porter method [5]) and creatinine (according to Popper). All of these tests were conducted in the same order and to the same extent in a control (background) survey of the same individuals, who maintained bed rest. We used a standard 2% water load test after 56 h in the water to assess the functional state of the kidneys and glucocorticoid activity of the adrenal cortex [6]. In order to differentiate between gravitational influences and functional changes in the adrenals, the water tests were conducted with the subjects in horizontal position, unlike the postflight tests. All of the results were processed by methods of variational statistics.

Results and Discussion

The subjects' general condition was satisfactory during the study; however, there were several symptoms typical of immersion: pain in the lumbar region after 6-8 h, which disappeared on the 3d day. Maceration of the skin of the feet associated with pain was another complication of prolonged immersion. One subject presented dermatitis associated with itching. Soon after the study these signs disappeared, and they did not require any special treatment. Two men suffered from impaired sleep at night, while the rest slept for 8-9 h without interruption. Appetite was good in all subjects, and there was no difficulty in ingesting food prepared in the usual way.

Table 1. Daily excretion of analyzed substances in the background period and during immersion

Period of study	Excretion				
	diuresis mℓ	Na, meq	K, meq	17-HCS, mg	creatinine, g
Background	960±140	218±38	55±12	5.4±1.1	1.5±0.2
Immersion, days:					
1st	1700±210	310±34	62±10	7.7±1.0	2.0±0.1
2d	1700±510	271±33	70±10	7.8±0.8	2.5±0.2
3d (water test)	3100±380	166±26	65±10	8.4±1.3	2.0±0.1

Upon analyzing the data in Table 1, one ca see that there was an increase in excretion of all tested substances after immersion, and it remained on a high level throughout the study period. On the 1st day of immersion, diuresis increased by 77%, sodium excretion by 42%, total 17-HCS by 43% and creatinine by 34%, as compared to the mean 24-h excretion in the background period. There was virtually no change in potassium excretion. On the 2d day of immersion, diuresis, as well as excretion of sodium, potassium and 17-HCS remained at the same level as on the 1st day, while creatinine excretion increased by another 24%. We paid special attention to the

dynamics of excretion of the substances under study, for which purpose we estimated the rate of excretion per 8-h segments of time throughout the period of immersion. These data are listed in Table 2. As can be seen, the 24-h rhythm of excretion of the substances under study was retained. At night, there was a decrease in elimination of these substances, and in the morning there was an appreciable increase. In the first half of the 2d immersion day (from 0800 to 1600 hours), there was maximum elimination of creatinine, sodium and potassium, as compared to the entire period of immersion. The increase in creatinine excretion is apparently related to the higher load on certain muscle groups. This could also explain the tenderness of the lumbar region.

Table 2. Rate of excretion of analyzed substances in the study with immersion in water

Parameter	BG*	Immersion, h							After immersion
		0–8	8–16	16–24*	24–32	32–40	40*–48	48–56	
Diuresis, mℓ/h	39±4	98±16	65±12	54±4	116±23	87±11	88±7	132±27	28±[illegible]
Excretion of:									
Na, meq/h	6.9±0.9	15.9±3.6	14.3±1.6	10.2±1	17.2±3.3	10.6±2.6	7.4±1.5	13.3±4.8	2.1±[illegible]
K, meq/h	1.5±0.2	4.0±1.2	1.8±0.3	2.7±0.2	4.9±0.8	2.[illegible]±0.3	3.0±1.0	4.9±1.8	0.9±[illegible]
17-HCS, μg/h	172±24	45[illegible]±97	300±40	292±69	436±56	314±69	298±52	465±112	161±[illegible]
Creatinine, mg/h	49±6	89±18	94±5	80±5	141±26	93±6	84±6	96±8	[illegible]

*BG--background; studies conducted at night.

During the 3 days of immersion, daily excretion of total 17-HCS was somewhat higher than in the background period, but because of the wide scatter of individual data this increase was statistically unreliable. Dynamic observation of different 8-h intervals revealed that, while the circadian rhythm of elimination of hormones in urine was retained, the rate of excretion was quite high. It must be noted that the mean 24-h level of 17-HCS excretion was elevated in view of the fact that 2 men tolerated immersion worse than the others.

In the 8-h period following termination of immersion (at night), there was a statistically significant ($P<0.05$) decrease in diuresis, as compared to the level the preceding night, as well as in excretion of sodium and potassium. At the same time, excretion of 17-HCS and creatinine decreased to background levels (see Table 2).

Immersion in water causes an increase in influx of blood to thoracic organs and triggers several reflex reactions, in particular, depression of secretion of antidiuretic hormone (ADH) and aldosterone [7, 8]. Moreover, there is an increase in rate of glomerular filtration [9], which was also observed in our study. Such a change in renal function and hormonal systems that regulate fluid-electrolyte homeostasis in the body, causes an increase in excretion of fluids and salts during immersion. Compensation of these losses begins immediately after returning to the usual living conditions and

change in hormonal and reflex influences. For this reason, one observes a drastic decrease in diuresis and excretion of electrolytes after returning to vertical position. The circadian rhythm of elimination of fluid, electrolytes and glucocorticoids is, as it has been demonstrated, a powerful physiological mechanism that retains its dominant significance during immersion in water as well.

A specialized study of renal function and glucocorticoid activity of the adrenals was conducted by means of functional tests with a water load, the diagnostic capabilities of which are well-known [1, 10-12]. Table 3 lists data on the rate of excretion of the substances under study with maximum water diuresis.

Table 3. Rate of excretion of analyzed substances with maximum diuresis following water load (20 mℓ/kg)

Parameter	Background	Immersion
Diuresis (mℓ/min)	14.7±0.8	13.4±1.1
Excretion of:		
Sodium, μeq/min	230±13	239±52
Potassium, μeq/min	54±5	85±15
17-HCS, μg/min	15.5±1.8	11.8±1.4
Creatinine, mg/min	1.6±0.1	1.7±0.2

As we see, the magnitude of maximum water diuresis did not change, as compared to the background period, and it was rather high. There was an increase in rate of excretion of potassium, while total 17-HCS excretion, on the contrary, presented a tendency toward decreasing; however, these changes were statistically unrelaible. Excretion of sodium virtually failed to differ from the background level, which also applied to excretion of creatinine, which characterizes the rate of glomerular filtration. A mean of 111±4% of the water load was excreted during the 4 h of the water test, versus 118±6% in the background period.

Thus, when we simulated the physiological effects of weightlessness by means of immersion in water we were unable to obtain the functional changes that had led us to expound at one time the hypothesis that the development of functional hypocorticoidism in weightlessness was one of the causes of endocrine metabolic disturbances during space flights. In the course of immersion for 60 h, there was no reliable decrease in excretion of overall 17-HCS in urine, while no fluid retention or saluresis was demonstrable in the water test. Apparently, the distinctions of volume regulation when changing to earth's gravity are of prime significance to the postflight changes in the water test.

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ERYTHROCYTE BALANCE DURING 182-DAY HYPOKINESIA

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[English abstract from source]

A prolonged head-down tilt resulted by the end of the second month in a significant decrease in the circulating blood volume at the expense of plasma and erythrocyte volumes. One of the factors that caused a reduction in the erythrocyte volume was their survival time shortening. The fact that during the rest four hypokinetic months there was no further decline in the erythrocyte count was attributed to adaptive developments: increase of bone marrow production and rate of differentiation of erythroid elements. Exercises used as a countermeasure could slightly counteract the adverse effects of head-down tilt.

[Text] At the present time, long-term hypokinesia with the body in antiorthostatic [head down] position is considered one of the models of weightlessness [1, 2]. Redistribution of blood in the body is the main pathogenetic factor, which leads to development of a set of symptoms that is similar to the one observed with zero gravity. Plethora of the upper part of the body is observed and, consequently, there is a decline in volume of circulating blood. Evidently, a change occurs in blood flow in parenchymatous organs, in particular, in the kidneys and spleen which, in turn, could lead to a change in delivery of oxygen to organs and thereby affect the mechanism of production of erythropoietin or hemolytic factor of the spleen. The above hypotheses cannot be considered confirmed experimentally; however, they could explain the impairment of kinetic balance of erythropoiesis [3-5]. Our objective here was to investigate the effect of prolonged antiorthostatic hypokinesia (AOH) on circulating blood volume and some parameters of kinetics of erythroid elements.

Methods

A total of 18 healthy men were kept on strict bed rest, with the bed tilted down at an angle of -4° for 6 months. Starting on the 7th day of

AOH, the first group of subjects underwent intensive physical training on a simulator (3 days of training + 1 day of active rest) for 1 h twice a day (energy "cost" of training constituted 500 kcal) and a course of electric stimulation of muscles. The subjects in the second group were submitted to physical exercise shorter in duration and energy expenditure starting on the 7th day: 20 min of warm-up exercises and 20 min of exercise on a bicycle ergometer in supine position 3 times a week. No preventive measures were used on subjects in the third group, and they remained on a strict regimen of restricted mobility. LBNP [lower body negative pressure] was used on subjects in the first and second groups on the 40th, 90th, 135th and 182d day and, in addition, they were given fluid and salt supplements.

Before AOH and on the 60th and 120th days of the study, we determined on all subjects the volume of circulating plasma (PV) using ^{131}I-labeled (5 μCi) human serum albumin. Circulating blood volume (BV) and erythrocyge mass (EM) were calculated on the basis of hematocrit value. We used the method of Ye. N. Mosyagina to determine the intensity of erythropoiesis; this method permits determination of erythrocyte (E) life span according to rate of maturation of reticulocytes in vitro [4]. Our modification of this method makes it possible to obtain such parameters as half-time of mature erythrocyte circulation $T_{½}$ E) and bone marrow production thereof (Q) using the following formulas:

$$T_{½ E} = \frac{1000 \cdot T_{½\,ret}}{r_0 \cdot 24} \text{(per day)}, Q = \frac{N_E \cdot 0.693}{T_{½\,E}} \text{ (thousands/mm}^3\text{/day)}$$

where r_0 is the number of reticulocytes before cultivation (per thousand, N_E is the number of E per mm^3 blood and $T_{½\,ret}$ is the half time of reticulocyte maturation obtained experimentally.

Erythrokinetic studies were conducted before and on the 46th, 86th, 135th and 180th days of AOH. The results were submitted to statistical processing. The paired Student criterion was used to determine reliability of differences.

Results and Discussion

Prolonged (2 months) AOH led to a distinct decline of BV. In some cases, this decline was in the range of 2 to 35%, as compared to base data. BV was 2-3% above the base level in only 2 subjects submitted to moderate physical exercise. There was the most significant blood loss in the control group, by a mean of 19.4% (versus 11 and 8% in the first and second groups) (Table 1). Blood loss was attributable to equal extents to a decrease in PV and EM ($P<0.01$).

The set of preventive exercises in both variants attenuated somewhat the adverse effect of AOH on the amount of blood. However, the differences between groups were statistically unreliable for all tested parameters.

Table 1. BV, PV and EM (ml/kg body weight)

Group	BV			PV			EM		
	Background	day examined		Background	day examined		Backgr.	day examined	
		60th	120th		60th	120th		60th	120th
1	67.0±3.4	58.7±2.3*	62.2±3.1	42.7±2.2	36.5±1.6*	36.1±1.6*	24.5±1.8	22.6±0.6	26.3±0.5
2	66.5±1.9	63.4±4.8	59.7±4.6	41.2±1.8	40.6±2.0	35.1±2.6**	25.3±1.1	22.8±[illegible].9	24.5±2.2
3	66.6±2.5	54.5±2.4**	40.9±1.5	32.7±1.7**	32.[illegible]±1.7**	34.6±2.4**	26.7±1.2	21.8±0.7**	23.0±1.2**

* $P<0.05$
** $P<0.01$

With longer bed rest (4 months), most subjects failed to demonstrate further decrease of BV, and in a number of cases there was even an increase. However, on the average, the amount of blood remained 6.4, 14.5 and 17.7% lower in the first, second and third groups, respectively.

On the 60th day of the study, EM diminished in all 5 control subjects. A distinct decline of EM was demonstrated in only half the subjects who exercised (in all, 6 subjects were examined from the 1st group and 4 from the 2d). In the others, EM either remained at the base level or was negligible higher than the latter. On the average, EM loss constituted 8.0, 10.0 and 19.4% in the 1st, 2d and 3d groups, respectively (see Table 1). For the next 2 months of AOH there was no further decrease in EM, while some increase thereof was even observed in individuals who underwent the set of preventive exercises, and it was more marked in those who exercised intensively.

Shortening of E life span could have been one of the causes of decreased EM. After 1.5 months of AOH, there was a decrease in half-time of E circulation in most subjects. This decrease was the most marked in the first group. However, no differences between groups was observed (Table 2). Thereafter, $1_{½}$ E did not change appreciable to the end of the study. The faster elimination of E from circulation caused a decrease in EM, but did not lead to development of the anemic syndrome. The relative amount of E per mm blood remained stable throughout the period of the study (see Table 2). However, in view of concurrent loss of plasma, this parameter cannot serve as a criterion of quantitative characteristics of erythron under hypokinetic conditions.

As shown by the results of determining bone marrow production of E, there was an increase in daily passage thereof into the blood stream on the 46th day of AOH

(see Table 2). Thereafter, the intensity of erythropoiesis increased only in the subjects who did not exercise. Activation of proliferative activity and faster differentiation of erythroid elements are possible causes of increased bone marrow production of E. In favor of the latter are our findings on half-time of reticulocyte maturation. As can be seen in Table 2, the rate of maturation of reticulocytes increased during AOH, and it was highest on the 86th day.

Table 2. Some kinetic parameters of erythroid elements

Group	Background	Day examined			
		16	90	135	150
	Half-time of erythrocyte circulation, days				
1	36.5±9.2	17.1±2.8	27.0±1.6	23.9±2.8	21.3±3.4
2	30.7±4.7	29.3±9.6	29.6±6.8	24.3±2.8	27.0±4.1
3	33.7±6.0	25.1±5.6	27.6±15.1	23.8±5.2	26.3±6.2
	Erythrocytes, millions/mm^3				
1	4.53±0.09	4.30±0.16	4.51±0.18	4.61±0.13	4.24±0.28
2	4.65±0.08	4.24±0.08	4.61±0.13	4.48±0.11	5.10±0.25
3	4.76±0.09	4.93±0.22	4.59±0.16	4.62±0.25	5.10±0.16
	Bone marrow erythrocyte production, thous/mm^3/day				
1	136.0±53.3	186.0±26.2	117.5±8.56	139.5±14.8	150.6±24.2
2	122.0±24.2	149.5±46.7	126.0±23.6	137.0±16.4	145.7±32.6
3	137.5±37.2	166.0±42.2	185.5±80.8	207.0±40.0	160.0±35.2
	Half-time of reticulocyte maturation, h				
1	10.2±2.9	7.2±1.6	4.0±0.5	6.6±0.8	5.5±0.6
2	7.3±0.9	6.5±1.4	6.1±1.4	7.1±0.4	4.9±0.5
3	9.0±1.9	8.6±1.9	5.0±1.6	9.3±2.5	6.2±0.9

Unfortunately, EM was not determined at the end of the hypokinetic period (6 months). However, in view of the dynamics of the parameters of erythrokinetics studied, it may be assumed that the erythrocyte balance remained on a stable level for the last 2 months.

According to data in the literature, the main hemodynamic changes, including the decrease in BV and PV, develop during the first week of strict bed rest in horizontal position [4-6]. At this time, an erythropoiesis inhibitor is demonstrable in plasma, with decreased erythropoietin activity [7]. Evidently, inhibition of erythropoiesis is one of the chief pathogenetic factors leading to a 7-13% decrease in EM, which most authors found by the end of the 4th week of hypokinesia [4, 6-8, and others]. In the case of strict bed rest with a negative tilt angle, there is more significant reduction of E mass and hemoglobin. This is indicated both by the results of our studies and data in the literature [9, 10].

The decrease in erythropoietic activity, which occurs at the start of hypokinesia, is not the only cause of decrease in EM. Under our experimental conditions, it was also attributable to a reduction in circulation

half-time and, consequently, life span of erythrocytes. The absence of further decline of EM during AOH (4th month, as compared to the 2d) and even some increase the [illegible]n, which was particularly distinct with the use of exercise, occurred as a result of intensification of erythropoiesis. According to the data of M. M. Shcherba et a. [10], the inhibitory properties of plasma disappear in the course of 49-day hypokinesia, and even some increase in erythropoietic activity is observed. Apparently, during this period committed erythropoietin-sensitive stem cells become involved in the process of activation of erythropoiesis. Indeed, studies on mice revealed that, during 60-day hypokinesia, bone marrow stem cells show a stronger capacity to form colonies of the erythroid type, as compared to the stem cells of intact animals [11].

As we have indicated, our findings are also indicative of activation of erythropoiesis, which was manifested by increased bone marrow production of mature E. In this case, the increase in rate of differentiation of erythroid elements, as demonstrated by the results of examining the half-time of reticulocyte maturation, is also one of the causes of faster passage of E into blood. However, this does not rule out the involvement of other mechanisms in this process: intensification of proliferative processes, reduction of generative cycle, predominant differentiation of stem cells in the erythroid direction, etc.

Thus, two phases are demonstrable of changes in erythrocyte balance during long-term hypokinesia. The first is characterized by inhibition of erythropoiesis, resulting from redistribution of blood at the very start of hypokinesia and associated with faster elimination of E from circulation, which leads to a decrease in EM after 1-2 months. In the second phase, there is prevalence of compensatory processes, manifested by activation of erythropoiesis. In spite of the faster elimination of E, the development of these processes prevents further decrease of EM and is instrumental in holding it on a somewhat low level, due to the diminished demands made of the oxygen-transport system.

Use of a set of preventive measures attenuates the adverse effect of AOH. However, the nature of the demonstrated adaptive reactions was the same, both in the case of pure AOH and with the use of physical exercise, regardless of its intensity.

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EFFECT OF PROLONGED ANTIORTHOSTATIC POSITION ON CARDIAC BIOELECTRICAL ACTIVITY ACCORDING TO EKG TRACINGS FROM CORRECTED ORTHOGONAL LEADS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 5, 1980 pp 54-59

[Article by V. D. Turbasov, submitted 22 Feb 79]

[English abstract from source]

The effect of the time of head down tilting on electrocardiographic parameters was consistent and significant ($P<0.05$): a slight increase in heart rate in groups 1 and 3, an increased time of atrioventricular conductance, an increased amplitude of the QRS complex, and a decreased amplitude of T wave, primarily in groups 1 and 3. No dystrophic signs were detected. The high level of heart rate in group 3 during the recovery period suggests a more pronounced decline of functional capabilities of the heart. There are grounds to believe that countermeasures produce a relatively greater effect on the function of the myocardium than on its metabolism.

[Text] Numerous clinical and experimental observations have shown that muscular activity is a most important condition for optimizing not only motor, but vegetative functions of the body. Disorders referable to vital functions, which arise as a result of drastic restriction of motor activity, are known in the literature as the "hypokinetic syndrome" and "hypokinetic disease" [1-3]. Worsening of the condition of the cardiovascular system is the prime factor in symptomatology of the hypokinetic syndrome [1, 4-8]. It is interesting to examine the bioelectrical activity of the heart during development of the hypokinetic syndrome in order to evaluate the morphological and functional state of the myocardium.

Methods

A study was made of 18 healthy men (3 6-man groups) ranging in age from 30 to 40 years, who remained in antiorthostatic (-4.5° head down tilt) position for 182 days of bed rest. The first group of subjects were submitted to a set of preventive measures, including exercise and a course of electrostimulation of muscles. They exercised for 60-65 min, twice a day, on a 4-day cycle (3 days of exercise, 1 day of active rest). Briefer and less intensive exercise was used on the second group of subjects: 3 times a week up to the 70th day, then 5 times a week. The third group was a control, and no preventive measures were used. The diet was approximately

balanced and conformed with expenditure of energy: 3300 kcal/day for the first group, 2900 kcal/day for the second and 2750 kcal/day for the third.

The EKG was recorded (corrected orthogonal leads according to Frank) on a Mingograph-81 instrument with a resistance-correcting attachment. We took the EKG in the mornings, before breakfast, at rest. The EKG was taken during the period of background examination, on the 6th, 46th, 70th, 110th, 154th, 172d days of antiorthostatic hypokinesia (AOH), and on the 34th and 53d days of the recovery period. We used the parameters proposed by E. A. Ozol for quantitative analysis [9]. In our vector analysis, angles H (azimuth) and E (elevation) were determined with a vectorcardiometer [10]. The data were submitted to statistical processing by means of two-factor variance analysis (factor A--duration of AOH, factor B--intensity of preventive measures) and the S method of multiple comparison using an M-220 computer.

Results and Discussion

The results of statistical processing are indicative of consistent changes in some EKG parameters, which are related to duration of AOH and intensity of exercise (Table 1).

Table 1. Results of two-factor variance analysis

Parameter	Factor	S^2	F_{exp}
HR, per min	A	287.8	4.91*
	B	106.9	1.82*
PQ, s	A	0.000959	2.20*
	B	0.000201	0.47
$R_x - S_y - S_z$, mV	A	0.53290	3.13*
	B	0.09823	0.58
$S_x - R_y + R_z$, mV	A	0.20960	2.10*
	B	0.10160	1.02
H, degrees	A	96.39	0.20
	B	110.60	0.23
E, degrees	A	93.22	0.71
	B	293.60	2.25*
T_x, mV	A	0.05275	3.80*
	B	0.02794	2.02*
T_y, mV	A	0.00720	1.18
	B	0.01041	1.71*
T_z, mV	A	0.7375	2.97*
	B	0.01663	0.67

Note: For A, $df = 8$, $F_{0.05} = 2.01$, and for B, $df = 17$, $F_{0.05} = 1.69$. The asterisks refer to reliable ($P<0.05$) influence of factor.

The mean heart rate (HR) during AOH failed to demonstrate statistically significant differences from both the background period and between different groups. HR changes were the least marked in the second group (Table 2). There was an appreciable increase in HR in all groups in the recovery period.

The mean value of this parameter exceed with statistical significance (P 0.05) all prior mean levels in the third group, as well as all means characterizing the other two groups.

The time parameters of the EKG (PQ, QRS, QT) remained within the normal range throughout the study period in all groups, and they conformed with the proper levels for the existing HR. The effect of the factor of duration of AOH was statistically significant (P<0.05) for only the PQ interval (see Table 1), which increased consistently (see Table 2); however, the difference between minimum (background) and maximum (154th-172d days of AOH) values, as well as between parameters of different groups, was not statistically significant (P>0.05).

Table 2. Dynamics of some EKG parameters

Parameter	Group	Background		AOH, days						Recovery period, 53d day	
				6		110		172			
		$\bar{V}$	S^2	$\bar{V}$	S^2	$\bar{V}$	S^2	$\bar{V}$	S^2	$\bar{V}$	S^2
HR per min	1	53,50	31,50	57,00	29,60	58,40	22,80	59,00	78,00	64,50	181,90
	2	60,50	51,90	57,33	20,27	56,33	35,47	61,00	58,80	64,33	46,67
	3	60,00	72,40	58,83	24,97	63,17	72,97	64,17	49,77	81,33	53,37
PQ, s	1	0,1417	0,0007	0,1583	0,0002	0,1640	0,0007	0,1550	0,0008	0,1433	0,0007
	2	0,1367	0,0002	0,1417	0,0001	0,1550	0,0004	0,1467	0,0001	0,1450	0,0002
	3	0,1317	0,0002	0,1400	0,0001	0,1583	0,0007	0,1617	0,0003	0,1350	0,0002
$R_x+S_y+S_z$, mV	1	1,7870	0,2037	1,7450	0,2786	1,8980	0,1706	2,0650	0,2072	2,1430	0,1403
	2	1,7670	0,1117	1,6870	0,0708	2,0850	0,0884	2,2370	0,1589	2,1480	0,1454
	3	2,0050	0,0985	1,8920	0,1914	2,0770	0,1681	2,3480	0,2683	2,2930	0,2176
$S_x+R_y+S_z$, mV	1	1,3180	0,1793	1,2580	0,2534	1,6840	0,1972	1,6220	0,1558	1,5130	0,1703
	2	1,1420	0,0856	1,2470	0,0521	1,5020	0,1326	1,4580	0,1153	1,35200	0,0523
	3	1,2820	0,0394	1,3370	0,0566	1,1760	0,0067	1,3700	0,0099	1,4820	0,0200
T_x, mV	1	0,5083	0,0364	0,3917	0,0484	0,3600	0,0054	0,4967	0,0149	0,5233	0,0231
	2	0,3083	0,0144	0,2500	0,0230	0,4417	0,0104	0,4233	0,0047	0,4317	0,0090
	3	0,4417	0,0164	0,3833	0,0206	0,3633	0,0016	0,4100	0,0068	0,3583	0,0149
T_y, mV	1	0,3000	0,0040	0,2333	0,0116	[illegible]	0,0136	0,2650	0,0033	0,2850	0,0038
	2	0,2500	0,0040	0,2167	0,0146	0,2833	0,0126	0,1850	0,0097	0,2150	0,0057
	3	0,2833	0,0027	0,2250	0,0078	0,1483	0,0010	0,1883	0,0023	0,1917	[illegible]
T_z, mV	1	0,3450	0,0118	0,3667	0,0187	0,3000	0,0162	0,3117	0,0149	0,4430	0,0200
	2	0,2583	0,0114	0,5250	0,0227	0,3833	0,0306	0,3617	0,0198	0,4217	0,0283
	3	0,3883	0,0116	0,5250	0,0438	0,2633	0,0105	0,2967	0,0105	0,3867	0,0142
E, degrees	1	39,92	163,5	36,92	149,8	44,60	163,3	40,00	204,4	37,33	86,47
	2	23,67	228,7	28,33	139,1	27,00	24,34	23,42	143,2	22,67	177,3
	3	30,72	101,2	36,33	101,8	25,58	36,74	26,42	19,74	29,30	[illegible]

The changes in P waves (shape, amplitude, duration) were inconsistent, and they had no clinical significance.

The effect of duration of AOH on aplitude parameters of the QRS complex ($R_x+S_y+S_z$ and $S_x+R_y+R_z$) was statistically significant (P<0.05), and was manifested by consistent increase thereof (see Tables 1 and 2). On the whole, there was relatively proportionate increase in potentials of the ventricles. This was confirmed by the results of vector analysis, particularly the bsence of significant changes in orientation of the QRS vector (angles E and H) according to the time factor (see Tables 1 and 2). Intergroup differences in size of angle F (see Table 1) were only present

at certain periods, namely on the 110th and 172d days of AOH. However, the differential diagnostic significance of these differences is questionable, in view of the variation of angle E in the background period (see Table 2).

The mean amplitude of T waves remained in the normal range in all groups. A decrease in amplitude of T waves was noted in all leads for subjects in the first and third groups, and only in the "y" lead for those in the second group. The statistically significant ($P<0.05$) difference in amplitude of T_x between the first and second groups of subjects, which was present in the background period, disappeared during AOH as a result of decline in amplitude of T_x in subjects of the first group and increase in the second. A maximum decrease in amplitude of T_y in the third group of subjects was noted on the 110th day of AOH, and it was statistically significant, as compared to analogous parameters for subjects in the first and second groups (see Tables 1 and 2). During the recovery period we observed a substantial increase in amplitude of T_x and T_z waves (it exceeded background levels in the first and second groups of subjects). T_y remained below background levels in all groups (see Table 2). We failed to demonstrate any changes in amplitude and shape of the ST segment throughout the study period that would enable us to qualify them as being pathological. The amplitude of the ST_j point did not exceed the normal range in any subject. The demonstrated changes in amplitude of T waves, in the absence of appreciable changes in their shape, as well as in the absence of changes in ST segment and Q-T interval, did not warrant interpretation of the changes in the repolarization process as being pathological.

The heart rate (HR) is one of the most informative parameters characterizing the functional state of the cardiovascular system [11-14]. An increase of HR was also noted in other studies involving long-term hypokinesia [5, 6, 13, 15]. In the opinion of most authors, the reaction of the cardiovascular system, manifested by increase of HR, is indicative of change in vagosympathetic regulation with prevalence of sympathetic influences, decreased conservatism of cardiac function and development of signs of deconditioning [1, 4-7]. An increase in HR could be due to stimulation of intracardiac adrenergic neurons under the influence of parasympathetic nerves. Stimulation of the parasympathetic nerves in the presence of stress could alter cardiac function, both by means of a direct influence on excitatory processes in the myocardium and, probably, by altering conditions of metabolic effect of epinephrine [16]. The less marked HR reaction of subjects in the second group durign AOH and in the recovery period could be indicative of less marked changes. On this basis, it may be assumed that the exercise program used in the second group was optimal.

The increase in duration of atrioventricular conduction is also apparently a consequence of the change in vagosympathetic regulation of cardiac function. The stabilizing effect on this parameter of exercise, the effect of which is manifested with both increase and decrease in time of atrioventricular conduction, may serve as indirect confirmation of this [17-19].

The increase in ventricular potentials at the early stage of AOH could be attributed to increased filling of the cardiac chambers, as a result of redistribution of blood and alleviation of venous influx [20-23]. The increase in amplitude of the QRS complex at later stages was, apparently, the result of increase in muscular mass of the heart. However, one cannot consider it unquestionable that there are factors under AOH conditions which could lead to intensified function and, consequently, increased load per unit cardiac mass. Compensatory hyperfunction is observed when there is increased filling and dilatation of the walls of the venous elements of the heart [24] under the influence of such inotropic factors as increased HR, increased concentration of catecholamines and Ca^{2+} [25-30]. We cannot rule out the influence of "intramuscular peripheral hearts," which are the chief "helpers" of the heart, since hypokinesia limits conditioning thereof, and the heart functions with constant relative stress under such conditions [31]. Exercise, which causes relatively more intensive function of the cardiovascular system than in seated or standing position, is an additional adaptogen in antiorthostatic position [32, 33]. It is not deemed feasible to single out the influence of any of these factors.

The genesis of EKG changes at the repolarization stage is complex, and it has not been definitively determined. It is impossible to rule out the possibility of influence of metabolic changes, even in the absence of changes in the ST segment and QT interval [20, 34]. Of the other factors, changes in systemic and intracardiac hemodynamics, fluid-electrolyte metabolism and extracardiac regulation could have the most marked influence.

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VESTIBULAR NYSTAGMUS IN RATS AFTER HYPOKINESIA AND PROLONGED ROTATION

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[Article by V. G. Ovechkin and A. A. Shipov, submitted 11 Mar 79]

[English abstract from source]

Changes in the latent period, number of beats, duration and frequency of the nystagmus were investigated in rats exposed to angular acceleration of an increasing value (10, 20, 30, and 40 degree/cm^2) after a 21-day exposure to hypokinesia per se or hypokinesia in a rotating device(with a radius of 141 cm, rate of rotation of 33.3 rpm, and acceleration value of 2 g). The hypokinetic rats showed nystagmic changes only with the lowest acceleration used (10 °/cm^2). The hypokinetic animals rapidly adapted to a repeated exposure to angular acceleration during the recovery period. A 21-day exposure to hypokinesia in a rotating device disturbed adaptation to a repeated effect of angular acceleration during recovery. Mechanisms of these effects are discussed. It is concluded that hypokinesia cannot be an adequate model for studying weightlessness effects on the vestibular function.

[Text] Ground-based model studies were condcuted in preparation of an experiment [1] to test the effects of weightlessness and artificial gravity (AG) on the functional system [2] of the semicircular canals. Prolonged restriction of movements was used as a model of the physiological effects of weightlessness. The protective effect of 1 G AG was stimulated by rotating animals on a centrifuge at an angular velocity with which the resultant vector of acceleration (centrifugal and acceleration of gravity) would constitute 2 G.

The results obtained from model experiments can be used to work on problems of gravitational biology and the AG problem.

Methods

Experiments were conducted on 30 male Wistar rats initially weighing 200-320 g. The animals were divided into three equal groups. The first consisted of rats submitted to 21 days of hypokinesia in box cages, the size of which could be adjusted; the second consisted of animals who also spent 21 days in similar cage and were submitted to rotation on a centrifuge (centrifuge arm 141 cm, 33.3 r/min, 2 G gravity [3] at the location

of the animals). The third group served as a control. The animals in this group were kept in ordinary cages.

All of the rats were in the same room, received the same diet, and were exposed to the same proportion of daylight and darkness. The centrifuge was stopped for 1 h daily, at the same time of day, when the animals were weighed, the cages cleaned, water dishes and feeders were filled.

We examined the characteristics of vestibular nystagmus, which appeared under the influence of increasing angular accelerations (10, 20, 30 and $40°/s^2$). The methods used were described in detail previously [4]. Nystagmus was rated on the basis of latency period, number of beats, duration and frequency. The animals were examined 2 weeks before the experiment, on the day it was terminated (0 day), on the 3d, 9th, 15th (first and control groups), as well as on the 4th, 11th and 18th days (second group) of the aftereffect period. The obtained data were submitted to statistical processing, with the use of Student's criterion ($P<0.05$).

Results and Discussion

The latency period of the nystagmic reaction was longer (reliably on 0 day) in animals submitted to 21-day hypokinesia under the influence of accelerations of 10 and $20°/s^2$, than in the control group. With accelerations of 30 and $40°/s^2$, no differences were demonstrable at any time. There were reliably fewer nystagmus beats on 0 day only with exposure to accelerations of $10°/s^2$. In successive examinations, this parameter gradually decreased in both groups of animals with all levels of accelerations, which was indicative of habituation to angular accelerations. The number of beats was reliably lower on the 9th, 15th and 18th days with accelerations of 40 and $30°/s^2$, on the 9th and 15th days with $20°/s^2$ and on the 15th and 18th days with accelerations of $10°/s^2$ in animals submitted to hypokinesia, as compared to animals in the control group (Figure 1a). There was approximately the same change in duration (Figure 1b) and frequency of nystagmus as in number of beats; however, there were no differences in parameters of compared groups of animals.

The latency period of the nystagmic reaction to accelerations of 10 and $20°/s^2$ was longer in the second group of rats than in animals of the first group on all days tested. With exposure to accelerations of $10°/s$, this increase was reliable on 0 and the 4th day. With accelerations of $30°/s^2$, the latency period was reliably longer on 0 day. We failed to demonstrate reliable differences between latency periods of nystagmus of animals in compared groups with exposure to accelerations of $40°/s^2$ (Figure 2a).

There were reliably fewer nystagmic beats in the second group of animals, on 0 day after exposure to all levels of accelerations than in the first group (Figure 2b). The level of significance of differences was extremely high ($P<0.001$) with accelerations of 40, 30 and $20°/s^2$. At the routine examination on the 4th day of the readaptation period, not only did the

number of nystagmic beats in the third and first group of animals fail to decrease, as compared to 0 day, it increased reliably in proportion to level of accelerations (see Figure 2b). On subsequent days, this increase slowed down somewhat, and there was a tendency toward decrease of this parameter. Nevertheless, even on the 19th day of the readaptation period, the number of nystagmus beats was increased with all levels of accelerations (reliably, with accelerations of 20, 30 and 40 $°/s^2$), as compared to 0 day. Analogous and even more marked patterns were also noted in duration of nystagmus (Figure 2c). Only a tendency toward such changes was demonstrable on the curves of dynamics of frequency of nystagmus.

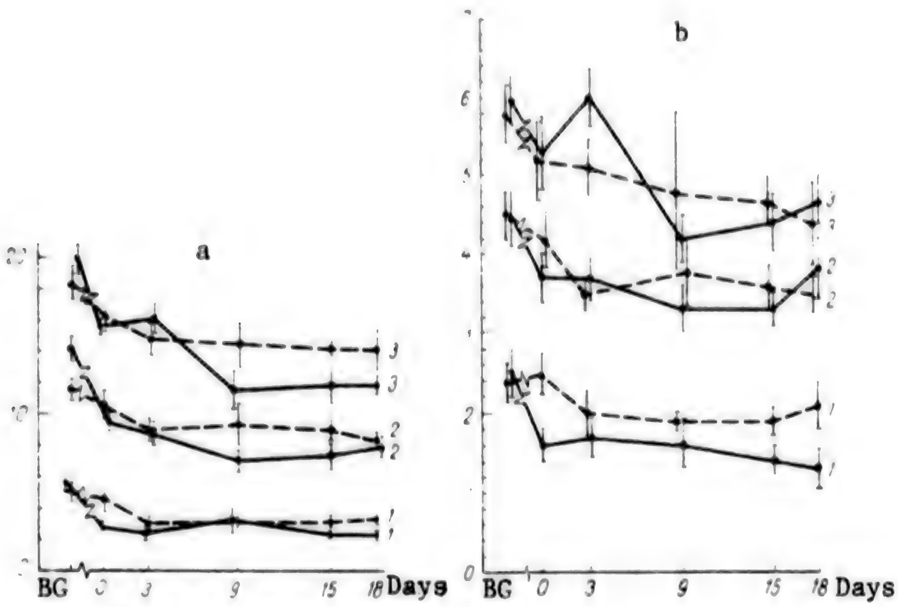
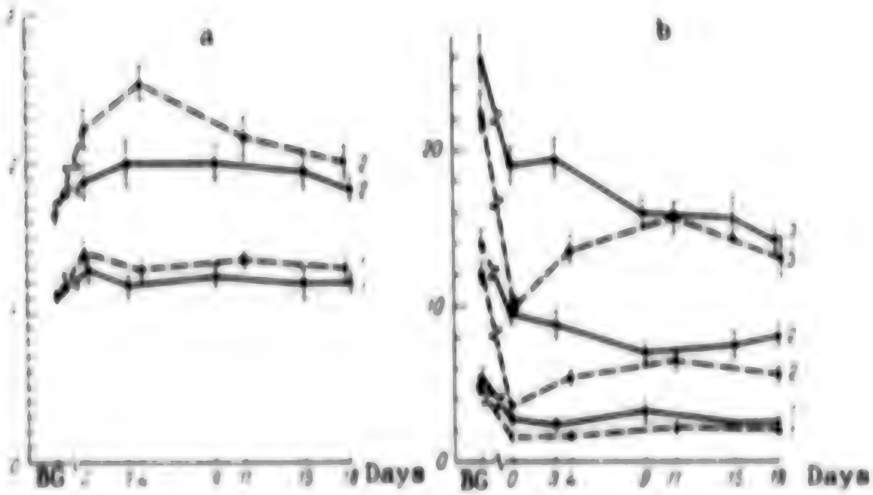


Figure 1. Number of beats (a) and duration (b) of nystagmus in recovery period following 21-day hypokinesia. Solid line--first group, dash line--control. X-axis day of examination
Key: 1, 2, 3) accelerations of 10, 20 and $30°/s^2$, respectively
BG) background,[here and in Figure 2]

According to previously published data [5], no differences were observed in the nystagmic reaction (according to parameters of number of beats, duration, mean frequency), as compared to control animals, were demonstrated on 0 day after 30-day restriction of movement of rabbits exposed once to accelerations of $40°/s^2$(lasting 9 s), as was the case in our tests on rats. The significant change we demonstrated in latency period on 0 day and the first few days of the readaptation period with the lowest of the accelerations used ($10°/s^2$) is probably attributable to the special sensitivity of this paremter to the functional state of the central nervous system in the case of low accelerations [6, 7], which was substantially altered after both hypokinesia [8, 9] and rotation [10]. The results

of the studies revealed that one may expect changes in other parameters of nystagmus as well on 0 day after submitting rats to low accelerations.



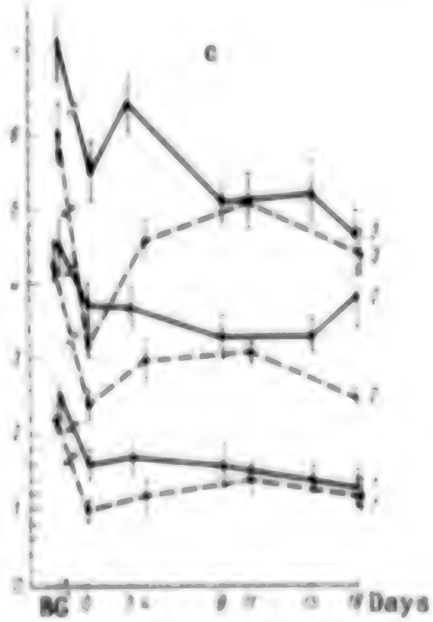


Figure 2.
Latency period (a), number of beats (b) and duration (c) of nystagmus in the recovery period after 21 days of hypokinesia with rotation. Solid line--first group, dash line--second group

a: 1, 2) accelerations of 20 and $10°/s^2$ respectively
b, c: 1, 2, 3) accelerations of 10, 20 and $40°s^2$, respectively

In rabbits [5], numerous exposures to accelerations of $40°/s^2$ at 5-min intervals on 0 day after hypokinesia failed to change the parameters of nystagmus, i.e., there was virtually no habituation to accelerations, as compared to the results of analogous tests on the control group of animals. It was assumed that disappearance of habituation of the vestibular system to repeated angular accelerations is related to drastic decline of adrenergic

function of rabbits following hypokinesia. Since the changes in activity of adrenergic and cholinergic systems after hypokinesia were the opposite [11] in rats, as compared to rabbits, with validity of the above hypothesis one could accept faster adjustment of rats after hypokinesia, which was observed in our study with regard to such a parameter of nystagmus as the number of beats. However, it is hardly possible to make a direct comparison of our results to the cited studies, since the intervals between examinations in [5] (minutes) differed substantially from those we used (hours).

The uniqueness of dynamics of nystagmic parameters in the aftereffect period following rotation is, in our opinion, attributable to the prolonged combined stimulation of the otolith system by centrifugal and Coriolis accelerations and stimulation of receptors of semicircular canals by precession accelerations [1]. It should be noted that the distinctive nystagmic reaction demonstrated in the second group of animals was confirmed in a study of rats submitted to artificial gravity aboard Cosmos-936 [1]. At the same time, animals submitted to weightlessness failed to demonstrate changes in nystagmic reactions that were observed following hypokinesia. Hence, it can be concluded that, unlike weightlessness [1], prolonged hypokinesia has a certain effect on the functional system of the semicircular canals. Consequently, the model of restricted movement is not adequate for simulation of the physiological effects of weightlessness on function of the vestibular system (at any rate, the functional system of the semicircular canals).

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UDC: 612.766.2-08:612.663-06:]577.16+577.118

EFFECT OF EXERCISE, VITAMIN AND MINERAL SUPPLEMENTS ON REPRODUCTIVE FUNCTION OF ALBINO RATS DURING PROLONGED HYPOKINESIA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 5, 1980 pp 63-65

[Article by Ye. A. Stroganova, Yu. F. Udalov, V. I. But, V. Ye. Potkin and I. V. Rogacheva, submitted 5 Oct 79]

[English abstract from source]

The effect of exercise and diet supplemented with vitamins and trace elements on the reproductive function of white rats exposed to 30-day hypokinesia was studied. Hypokinetic females in a regular diet produced offspring in 33 % and those on an enriched diet in 50 % cases. The same values were obtained in exercising rats, the time allowed for their exercises making 3 % of the total experimental time. A combined use of an enriched diet and exercises resulted in a 100 % increase of pupping events.

[Text] It has been established that there is an increase in requirements for some vitamins and minerals under hypokinetic conditions [1-4]. It was proven experimentally that hypokinesia has an adverse effect on skeletal development and mineral metabolism of offspring, as well as reproductive function of adult animals [5, 6]. All this makes it imperative to find appropriate preventive measures. Our objective here was to try to examine the effect of exercise and dietary supplement of vitamins and trace elements on some parameters of reproductive function in hypokinetic albino rats.

Methods

Experiments were conducted on 45 mongrel rats 7 months of age. The animals were divided into five groups: the first group consisted of rats submitted to hypokinesia; the second consisted of animals kept under hypokinetic conditions and given vitamin- and mineral-enriched feed; the third was made up of rats kept under hypokinetic conditions and exercised; the fourth consisted of animals kept under hypokinetic conditions, which exercised and received vitamin and mineral supplements; the fifth was a control group. There were three males and six females in each group. To create hypokinesia, the experimental rats were placed in special plastic box-cages, which restricted their movement but did not hinder feed and water intake. Control animals were kept in ordinary vivarium cages, 6 in each.

The animals received feed and water ad lib. Daily (except for days off) swimming in a tub of water at +27°C for 30 min was used as exercise. The animals were given a vitamin and mineral supplement (0.1 g of each) daily with their feed. The supplement contained vitamins constituting 0.15 dose of Aerovit, which is recommended for hypokinetic conditions and weightlessness [7], lipoic acid amide (0.25 mg), trace elements (copper, zinc, cobalt, manganese and iron in doses of 0.1, 0.25, 0.015, 0.35 and 0.7 mg, respectively) and magnesium (0.5 mg). Calcium phosphate was used as filler (up to 100 mg). Phosphorus and calcium content referable to the filler constituted at least 8.5 and 7 mg, respectively.

Table 1. Dynamics of weight changes in experimental rats, g

Hypokinesia, days	Sex	Group				
		1	2	3	4	5
10	Males	194±13.4*	227±24.3	229±17.6	236±20.6	241±9.2
	Females	173±2.0*	178±9.4	167±7.6	164±4.4**	201±8.9
20	Males	191±12.6**	224±26	121±12.2*	247±16.8	264±12.6
	Females	171±1.8**	177±8.0*	164±5.31**	172±5.0*	209±10.1
30	Males	191±16.8**	220±23.9	228±6.3**	233±16.4	255.7±3.3
	Females	179±3.5*	184±8.7	174.5±6.7*	175.5±4.2*	203±9.6

Note: Here and in Table 4, one asterisk indicates P<0.05 and two--P<0.01.

Table 2. Reproductive capacity of rats

Group	Total females in group	Females with offspring	Rats per litter
1	6	2	8.5
2	6	3	8.67
3	6	3	9
4	6	6	8.67
5	6	4	8.25

Table 3. Dynamics of weight changes in baby rats, g

Group	Rats in group	Baby rat wt., g	
		at birth	10 days after birth
1	17	5.5±0.7	13.4±0.3
2	26	6.2±0.2	14.9±0.4
3	27	6.5±0.5	16.6±0.5*
4	52	5.9±0.4	15.3±1.3
5	33	5.9±0.1	13.4±0.9

The rats were weighted on the 10th, 20th and 30th days of hypokinesia. After 30 experimental days, males from corresponding groups were put with the females. The males were removed from the females a few days prior to giving birth. The offspring from animals in each group were weighed on the 1st and 10th days.

The baby rats were sacrificed under ether anesthesia at the age of 30 and 60 days, and internal organs were weighed. The obtained data were processed by the Student method of variation statistics.

Results and Discussion

The base weight of males and females constituted 231±10 and 171±2 g, respectively. The animals in the control group weighed more 10, 20 and 30 days after the start of the experiment (Table 1). The experimental animals weighted less than the controls ($P<0.05$). The only exception was referable to the males in the fourth group, whose weight was somewhat above the control level. The lag in weight gain is one of the adverse effects of hypokinesia, which is due to metabolic changes, in particular a decrease in synthesis of nucleic acids and protein [8]. It was found that the weight of females in the fourth group was negligibly lower than that of females in the first group after 10 and 30 days of hypokinesia, whereas after 20 days of hypokinesia it was the same. However, the males in the fourth group weighed more at the above times than those in the first group. Consequently, a brief exercise period and a supplement of physiologically active nutrients were instrumental in retention of the weight of experimental animals on control levels.

Table 4. Weight of internal organs of rats at the age of 1 and 2 months, mg

Organ	Sex	Group of baby rats				
		1	2	3	4	5
Heart	Male	173±1.73**	156±5.79	270±21.2*	213±25.2	197±3.16
	Female	168±1.73	177±8.84	374±16.8	197±7.0	172±1.73
Lungs	Male	309±21.8	265±31.1*	389±3.41**	309±12.1**	353±3.16
	Female	300±13.2	331±71.7	422±43.4*	326±14.2*	273±19.0
Liver	Male	1671±56.9	1206±62.0**	2221±59.2	2097±187	1716±93.6
	Female	1683±144	1411±276	2336±219*	2020±130*	1557±68.9
Spleen	Male	119±5.04**	140±7.51*	211±13.2**	123±6.76*	148±5.36
	Female	120±15.1	121±10.6**	183±30.9	125±6.05**	93.2±5.88
Kidneys	Male	438±19.3	376±16.9**	592±103	453±12.4	471±19.1
	Female	406±21.3	453±6.19	636±36.3**	471±17.4*	428±1.73
Adrenals	Male	15±3.08	11.6±2.57	16±5.3	14±1.36	17.7±1.99
	Female	17.8±2.8	16.3±2.65	23±1.76**	18.4±4.08	10.7±0.84
Thyroid	Male	14±1.12	10.8±1.93	17.5±9.73	11.4±0.75	17.6±3.29
	Female	11.5±1.12	17.5±2.65*	14.5±2.65	13.5±0.69	10.5±1.4
		Age: 2 months				
Heart	Male	361±25.1	338±14.2		389±25.5	378±31.4
	Female	345±26.7	391±103	497±53.9	348±21.4	382±19.0
Lungs	Male	509±10.9**	503±61.3	—	513±28.5	575±21.8
	Female	453±20.5*	496±43.3	658±280	537±61.6	548±19.2
Liver	Male	4333±140	2800±251	—	3761±334	3900±504
	Female	3867±266	2850±88	5175±398*	3244±262	3520±313
Spleen	Male	350±41.5	260±14.7	—	326±43	393±72.3
	Female	331±19.5	293±38.0	356±99.1	249±12.4**	390±35.8
Kidneys	Male	879±19.3	738±54.1	—	867±61.1	886±12.7
	Female	709±58.1*	773±156	1099±353	778±65.3	856±35.1
Adrenals	Male	32±5.04	26±2.1	—	29.4±2.02	28.7±3.37
	Female	28.5±2.65*	31±14.2	42.5±15	31±2.5	30.7±1.95
Thyroid	Male	51±19.3	56±12.6	—	46.1±6.54	78.2±1.65
	Female	48.3±7.95	795±40.79	72.5±6.19	61±7.07	80.5±11.7

Note: There were 4, 5, 4, 7 and 11 month-old males in the first to fifth groups, respectively, and 4, 4, 4, 13 and 4 females. There were 3, 3, 1, 9 and 4 2-month old males, 6, 3, 3, 9 and 10 2-month old females.

Hypokinesia altered the sexual behavior of the animals (for the first few days the females would not let the males come close). It was established (Table 2), that the lowest reproduction percentage was referable to the first group (33%), the figure was 50% in the second and third groups, and in the fourth group all females had offspring. Reproduction constituted 67% in the control group. It should be noted that the lowest percentage of female reproductivity was referable to animals kept under hypokinetic conditions without preventive measures, and this is probably related to changes in the neuroendocrine system that regulates reproductive function.

The birth weight of rats born to the second and third groups was somewhat higher than in the control (Table 3); it did not decline after 10 days, constituting 110.8 and 123.2% in the second and third groups, respectively, as compared to the control. This difference was reliable. No appreciable differences were noted in the first and fourth groups, as compared to the control. While the birth weight of baby rats in the fourth group corresponded to the control level, it was 13.8% higher after 10 days. It was also demonstrated that the weight of most viscera of baby rats in the first group (both males and females) at the age of 1 and 2 months was lower than the control level (Table 4), whereas in most animals of the third and fourth groups, on the contrary, it was above control levels at the age of both 1 and 2 months.

Thus, we demonstrated impairment of reproductive capacity under the influence of hypokinesia in rats for whom no preventive measures were taken, and this was manifested by diminished sexual activity of animals in the posthypokinetic period and decrease in percentage of females that produced offspring. The use of exercise and enrichment of feed with a set of vitamins and minerals had a beneficial effect, improving reproductive function of the rats.

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STUDIES OF CENTRAL AND REGIONAL HEMODYNAMICS BY ISOTOPE AND IMPEDANCE METHODS DURING LBNP

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 5, 1980 pp 66-70

[Article by Kh. Kh. Yarullin, T. V. Benevolenskaya, V. I. Lobachik, T. D. Vasil'yeva, V. A. Gornago, V. V. Degtyarenko and N. F. Tarasov, submitted 8 Feb 79]

[English abstract from source]

The potential of impedance and isotope (intravenous injections of ^{131}I and ^{113m}In) methods to study regional and central hemodynamics was investigated on 12 test subjects exposed to LBNP. Both methods demonstrated marked changes in blood filling of the head and the chest, particularly during the first minutes of LBNP tests. This occurred together with a drastic increase in leg blood filling. The close similarity of regional hemodynamic changes detected by the two methods gives evidence that the simple and noninvasive impedance method can be well used for the above studies.

[Text] LBNP [lower body negative pressure] is being used more and more in aerospace medicine to determine the functional capabilities of the cardiovascular system and detection of disorders thereof. Yet the mechanisms of redistribution of blood and changes in regional hemodynamics during this test are not quite clear, and they have been little-studied. Our objective here was to make a comparative study of changes in central and regional hemodynamics by the inpedance and radioisotope methods occurring with LBNP.

Methods

The belt of the decompression device was sealed at the level of the iliac crest of each subject in supine position. Hemodynamics were studied with the use of LBNP increased in steps (2 min of 25 mm Hg, 3 min of 35 mm Hg, 5 min of 40 and 50 mm Hg) in 12 healthy male volunteers 26-38 years of age, using radioisotope and rheographic methods simultaneously. We determined circulating blood volume on a well counter. The subjects were given intravenous injections of tracer doses of a mixture of radioisotopes

(^{131}I-labeled human serum albumin and ^{113m}In indium citrate). Both tracers mixed uniformly with blood, and they presented no tropism for organs and tissues. The distribution and migration of blood were determined by radiometry, using scintillation detectors in five regions of the body: head, chest, lower extremities and cardiac region (using 4 vertical lead shields). Concurrently, we recorded rheoencephalograms (REG) on a 4-RG-1M rheograph in the frontomastoidal and bimastoidal leads, rheograms (RG) of the lung and leg, EKG in 12 leads using a Mingograph, as well as arterial pressure by the method of Korotkov. The working frequency of the rheograph was 120 kHz. The RG was recorded on an 8-channel electroencephalograph with a time constant of 1 s. To record the RG of the lung, lead electrodes were placed in the region of the projection of the right lung: anteriorly in the second intercostal space along the medioscapular line (3×4 cm) and posteriorly on the level of the 4th-7th thoracic vertebrae at the scapular angle (12×6 cm); to record the RG of the right crus, we used a longitudinal lead (lead electrodes, 20×2 cm), and for rheoencephalography we used round, silver-plated brass electrodes 18 mm in diameter.

Pulsed delivery of blood to the regions under study was measured according to maximum RG amplitude (in ohms). We also calculated the relation of the anacrotic phase (α) of the tracing to duration of the cardiac cycle (T), dicrotic (DCI) and diastolic (DSI) indexes, which reflect respectively the tonus and elasticity of vessels of large and medium caliber, small arteries and arterioles, veins and venules.

Results and Discussion

The results of the isotope studies revealed that, under the influence of LBNP, all subjects presented a decrease in delivery of blood to thoracic organs and, to a lesser extent, to the head, as a result of shifting of blood to areas of low pressure [1, 2]. The most marked change in filling was observed at the start of the test (Figures 1 and 2). Thus, with rarefaction of 25 mm Hg, there was a group mean of 19% decrease in filling of the thoracic cage and 15% in that of the head, as compared to the background. With further rarefaction steps, the decrease occurred in these regions at a slower rate than at the start of exposure. At the last stem (-50 mm Hg), there was 27% decrease in filling of the chest, as compared to the base level. According to the data on the rheopulmonogram, the decrease in pulsed delivery of blood reached 37% in the first min (-25 mm Hg) and 41% in the last min (-50 mm Hg) of the test, and it was associated with significant increase in tonus of pulmonary vessels (α/T ratio increased by 33.1% and DCI by 53.2%). As we see, there was more marked decrease in pulsed filling of the lungs (the levels of which were close to those cited in the literature [3]) than of the entire thoracic cage, and it was associated with compensatory constriction of pulmonary vessels [2].

The individual distinctions of the reactions to the LBNP test are of great interest to evaluation of the changes in regional hemodynamics and

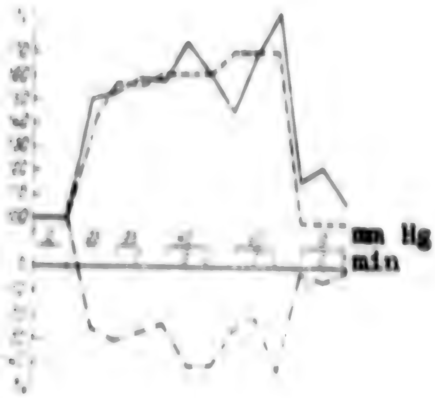

Figure 2.
Dynamics (% of background) of mean value for delivery of blood to thigh (^{131}I tracer, dash line) and pulsed delivery of blood to veins (solid line) and arteries (dash-dot line) of the crus, demonstrated by rheography on 12 subjects submitted to LBNP

Figure 1.
Dynamics (% of background) of delivery of blood to the head (^{131}I tracer, solid line) and thorax (^{113m}In tracer, dash line; and ^{131}I, dash-dot line) in subjects G. (a) and Ye. (b) during LBNP test

bioelectrical activity of the heart. Thus, the decrease in delivery of blood to the head (according to isotope test) did not decrease 15% in 4 subjects throughout the test; in these same cases pulsed delivery of blood to the right hemisphere (according to REG dynamics) did not decrease by more than 25.7%. In 2 subjects, a syncopic state developed in the 3d min of the test (-35 mm Hg). In one of them, there was a drastic decrease in maximum amplitude of the REG in the frontomastoidal lead in the first min of such exposure: pulsed filling of the hemisphere decreased by 73% and that of the vertebrobasilar basin by 58% (according to bimastoid REG), while the figures for the second subject were 50 and 68% of the base level, respectively, against the background of significant decrease in tonus of cerebral arterioles (DCI from 73-76 to 40.4-35.0%). Delivery of blood to the head, as determined by the isotope method, decreased more significantly in these cases, by 27% (see Figure 1a) than in subjects with good tolerance (only 15%). The decrease in pulsed filling of the lungs did not exceed 35%, and that of the entire thorax 17%, against the background of appreciable changes on the EKG in all 12 leads, which enabled us to interpret the syncopic state as a reaction of cerebrovascular genesis.

A comparison of EKG parameters to the results of the radioisotope and impedance studies also revealed some distinctions in the reactions. In two cases, along with development of a presyncopic state, we found EKG changes indicative of impaired delivery of blood to the myocardium. On the basis of radioisotopic test findings, these subjects presented more marked decrease in filling of cardiac chambers (by 15%, as compared to the background) than other subjects at the very first level of rarefaction.

With rarefaction of -35 mm Hg, one of them (Ye.) presented further and more significant decrease in filling of cardiac chambers, down to 71% of the base level (see Figure 1b). According to data from the RG of the lung, pulsed delivery of blood decreased by 85% in this subject and by 58% in the second one (K.), as compared to background levels. At this time, on the EKG of subject Ye., there appeared a deformity of $T_{V_{1,2}}$, to a lesser extent in T_V and an increase in P_V. In subject K., there was slower decrease in filling after a marked decrease in delivery of blood to the thorax at the first level of LBNP. In this subject, changes in the EKG (inversion of T_D and double-peaked T_A) were observed in the 1st min of the test, i.e., at the time of severe worsening of delivery of blood to the thorax, and they persisted to the end of the study. At the last level of LBNP, the EKG signs of myocardial hypoxia advanced somewhat (more distinct dual peaks of T_A and flattening of T_D). Pulsed delivery of blood to the cerebral hemisphere decreased by only 28% in subject K. and by 32% in Ye., while delivery of blood to the head decreased by 15 and 17% of the base level (see Figure 1). In other words, in both cases, the significant decrease in delivery of blood to thoracic organs, primarily the heart, was the cause of the presyncopic state. These findings, combined with marked EKG signs of myocardial hypoxia, enable us to interpret the presyncopic state of the subjects as a reaction chiefly of the cardiac type.

In the other three subjects, who presented a presyncopic state of the mixed cardiovascular type, presyncope preceded marked decrease in delivery of blood to both the chest and head.

Thus, as a result of synchronous isotopic and impedance studies of regional hemodynamics, we demonstrated a difference in mechanisms of development of presyncopic and syncopic states under the influence of LBNP. In some cases, they occur as a result of development chiefly of cerebral ischemia, in others as a result of myocardial ischemia, or as a result of poor circulation in both the heart and brain. These data confirm the possibility of occurrence of three types of presyncopes and syncopes under the influence of LBNP [4-6].

A significant decrease in delivery of blood to the thorax (by 26.7%) was observed in two other subjects (B. and M.). In spite of this, the pulse rate, pulse pressure and EKG parameters changed within the range that is inherent in a good reaction to the factor used. The pulse rate did not

exceed 80-88/min, pulse pressure was 40 mm Hg, and only a minor decline of $Tv_{5,6}$ on the EKG (without shifting of PST segment). Consequently, the decreased filling of the heart was not associated with poorer delivery of blood to it in all cases. Evidently, the coronary arteries of the heart, the functional distinctions of which provide for more or less adequate delivery of blood to the heart, even with diminished filling thereof, play the leading role.

It is known that the pressure difference between the top and bottom halves of the body causes blood to shift in the direction of lower pressure [1-6]. As can be seen in Figure 2, the mean value for filling of the right thigh increased drastically in all subjects already in the first min of the first level of rarefaction to 140%, reaching 167% of the base level ($P<0.001$) in the last min (-50 mm Hg). The mean DSI on the RG of the right leg, which reflects the magnitude of pulsed filling of veins, was superimposed over the isotope curve of femoral filling almost over the entire test, i.e., there was virtually total correlation between them. Indeed, already in the first min of rarefaction, pulsed filling of the veins exceeded the base level by 150% and by the end of the last step of rarefaction, by 180% ($P<0.001$). On the other hand, pulsed filling of the arteries (arterial influx) diminished appreciably, by 26% at the very start of the test and 45% at the end ($P<0.001$), as compared to the base level, which is consistent with the data of Montgomery et al. [9], who also observed a significant decrease in blood flow in the area submitted to LBNP. The mean index of blood flow in the region of the pelvis and upper third of the thigh decreased, according to these authors, in healthy males (20-36 years old) by 39 and 41% with LBNP of 40 and 60 mm Hg.

While the isotope method demonstrated only drastic increase in overall filling of the lower limb, rheography showed plethora of the lower limb [1, 6], as well as the arterial and venous components [2]. In the area submitted to LBNP (i.e., the lower extremities), there is overfilling of veins, at first due to shifting of a large volume of blood and then because of markedly labored venous efflux [1, 2, 4, 6, 9]. At the same time, there was restricted influx of blood to the legs due to decreased cardiac output, as a result of decreased venous return and compensatory constriction of small arteries and arterioles [2, 6], as indicated by the increase in DCI of the RG of the leg to 150% of the background level.

Thus, the use of the above-mentioned methods expanded the possibilities for examining hemodynamics. The radioisotope method yielded reliable information about the topography of blood redistribution with the use of LBNP. The impedance method enabled us to define the nature and form of hemodynamic changes. As a result of these studies, we demonstrated a distinct correlation between the hemodynamic parameters obtained with these methods, particularly in the area affected by LBNP. This is an important circumstance, since a number of factors (invasiveness, radiation loads, complicated and expensive equipment, etc.) limit the use of radioisotope tracers. The impedance method is simple, noninvasive, and it can be used on a wider scale.

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CHANGES IN MAIN PARAMETERS OF HUMAN HEMODYNAMICS WITH LOWER BODY COMPRESSED IN A G SUIT

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 5, 1980 pp 70-73

[Article by L. I. Letkova and K. I. Murakhovskiy, submitted 11 Mar 79]

[English abstract from source]

Changes in cardiovascular parameters of test subjects wearing anti-G suits were studied under static conditions. The study was carried out, using methods of radioactive label dilution, radiocardiography and tetrapolar rheography. The study demonstrated the highest level of physiological reactions within short transition periods after inflation and deflation of suit bladders.

[Text] At the present time, studies are continuing to refine the means of of protection against accelerations [1-4]. This work is part of one of these studies. Publication thereof by itself is justified, in view of the specifics of the problem studied: investigation of distinctive features of reactions of the circulatory system to compression of the lower part of the body in an anti-G suit (AGS) under static conditions. These studies are also interesting because mechanical pressure over the lower part of the body is finding applications in clinical practice, in the treatment of cardiovascular d'seases (for facilitation of venous return). The importance of examining this question is also due to the practice of long-term space flights, when we are dealing with improvement of orthostatic stability of cosmonauts in the postflight period.

Methods

We conducted our study on 8 healthy males ranging in age from 18 to 40 years. In all, 19 tests were conducted. These subjects sat in a mock-up of an aircraft chair wearing the AGS. Each of them was submitted to a background examination, during which the base hemodynamic parameters were obtained. A pressure of 0.3 kgf/cm^2 was created in 2-3 s in the AGS 30-40 min after the examination; this caused occlusion of underlying vessels of the lower extremities. In eight studies, 2-3 min after

setting the above pressure, the subjects were given intravenous injections of a radioactive tracer. Total exposure time was limited to 9 min, after which the pressure in the AGS chambers was rapidly lowered. In the studies where radioactive substances were used, we took venous blood for determination of circulating blood volume (BV) and to calibrate the radiocardiogram (RKG) curve. In the course of the study, we recorded the heart rate (HR), arterial pressure (AP), RKG, rheoplethysmogram, rheogram and differential rheogram of the thoracic region. An NS-110 "radiocirculograph" [7] was used to record the RKG. An NaI/Tl collimated scintillation sensor was used, which was centered in the region of the cardiac projection, on the level of the fourth intercostal space along the parasternal line. We used ^{131}I-labeled albumin solution as the tracer. The activity of a single test dose constituted 25-30 μCi. We used the analytical method, with a computer, as modified by F. F. Kaperko et al. [5] to determine the area under the RKG curve, which was required for subsequent calculation of hemodynamic parameters. From the RKG, we calculated minute (MV) and stroke (SV) volumes of the heart, pulmonary blood volume (PBV), mean total circulation time and circulation time over the vascular system of the lungs [6, 7]. Circulating blood volume was determined by the conventional method of dilution of radioactive tracer.

A domestic tetrapolar two-channel RPG2-02 rheoplethysmograph was used to record the rheograms, differential rheogram and rheoplethysmogram. The active electordes were placed over the perimeters of the neck and chest under the xiphoid process. The overall area of these electrodes constituted 150 cm^2. SV was calculated using the following formula:

$$MV = 150 \cdot \frac{l^2}{z_0^2} \cdot \frac{dz}{dt} \cdot \tau$$

where 150 is the specific resistance of blood at a temperature of 37°C (Ω/cm); l is the distance between recording electrodes (determined from the sternal line)(in cm), τ is the duration of the mechanical systole of the heart (s), dz/dt is the maximum amplitude of the differential rheogram (Ω/s) and z_0 are impedance readings (Ω) [8, 9]. In our calculations we took the averaged amplitude of the signal over 1 or 2 respiratory cycles. The duration of the mechanical systole of the heart was calculated in a similar manner.

Determination was made of cardiac work (W) and total peripheral resistance (TPR) on the basis of rheographic data and AP, using the following formulas:

$$W = MV \cdot \left(P_d + \frac{P_s - P_d}{3}\right) \cdot 1{,}316 \cdot 10^{-4} \quad \text{(kg-m/min)},$$

$$TPR = \frac{\left(P_d + \frac{P_s - P_d}{3}\right)}{MV} \cdot 60 \cdot 1333 \quad \text{(dynes·s/cm}^5\text{)},$$

where P_s and P_d are systolic and diastolic pressure (mm Hg), respectively at the time of recording the RKG. All of the data were submitted to statistical processing with calculation of means for time, mean differences of variants related in pairs, standard errors and Student criterion.

Results and Discussion

When pressure of 0.3 kgf/cm^2 is created in the AGS chambers, the underlying vessels of the lower limbs are occluded due to elevation of systolic AP, substantial increase in intraabdominal pressure and ejection of blood from the compressed areas. Figures 1-3 illustrate the effects of this factor on the main hemodynamic parameters. At first, after creating pressure in the AGS chambers, there is a decline of SV which, with the negligible change in HR, leads to marked decrease of MV. By the 20th s of compression, there is an increase in SV and MV, against the background of some tendency toward relative bradycardia. At this time, AP (both systolic and diastolic) is elevated. Cardiac work increases, while TPR has a tendency toward decreasing. Thereafter, against the background of virtually unchanged HR, there is gradual, relative decrease of SV and MV, these parameters coming close to base values. AP remains elevated. Pulse pressure decreases somewhat due to relatively greater elevation of diastolic pressure. TPR increases, while cardiac activity remains on a level that is reliably higher than the base level. Additional information about the state of circulation was provided by the results obtained with one-time use of the radioisotope method in the 3d min of compression. At this time, BV decreased reliably by 7%, while blood volume in pulmonary vessels increased by 20%. Data indicative of increased filling with blood of the pulmonary circulation under analogous conditions are encountered in the literature [1, 2]. As a result of cessation of blood flow in the lower limbs and increase in circulating blood in the pulmonary circulation, there is a reduction of total blood circulation time, whereas time of passage over the vascular system of the lungs increases.* In the aftereffect period, the

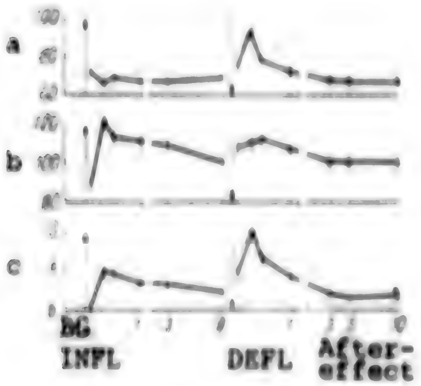

Figure 1.
Dynamics of HR (a, per min), SV (b, in mℓ) and MV (c, in ℓ/min) with inflation (INFL) and deflation (DEFL) of AGS chambers. X-axis, time (min). Arrows show time of INFL and DEFL; columns indicate standard error of means. BG--background

*We measured MV and SV simultaneously by radiocardiography and rheography in the 3d min. Statistical analysis by the method of variants related in pairs failed to demonstrate reliable differences between rheographic and radiographic readings.

vascular system of the lower extremities is included in the circulation and there is normalization of intraabdominal pressure. These signs are associated with marked decline of TPR and AP. The HR increases in response to the AP drop, and this in turn leads to significant increase of MV, in spite of the fact that there is relatively mild increase in SV. At this time, there is a tendency toward increased cardiac function. Virtually complete normalization of hemodynamics is observed by the 3d min of the aftereffect period.

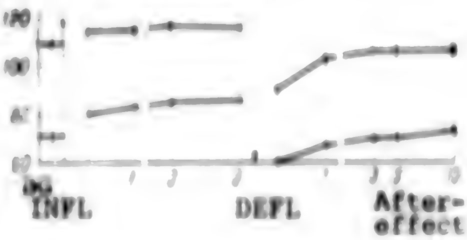

Figure 2.
Changes in AP (mm Hg) in the course of the study and aftereffect period. Here and in Figure 3: x-axis is time (min)

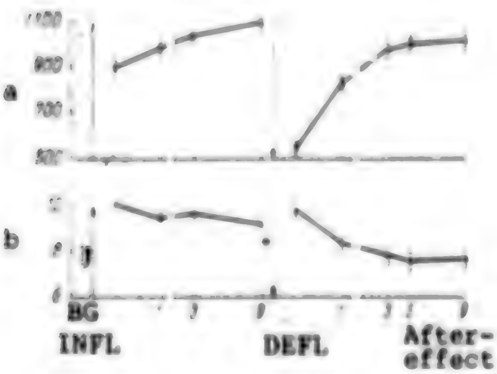

Figure 3.
Changes in TPR (a), dynes s/cm^5) and cardiac activity (b, kg-m/min) during the study and in aftereffect period.

We consider two factors, which are related to occlusion of vessels in the lower limbs and elevation of intraabdominal pressure, as the main cause of the above-described changes. The first is the increase in peripheral resistance and the second is redistribution of blood to the upper part of the body. One should relate the relative elevation of diastolic AP, as well as decrease in SV immediately after producing pressure in the AGS chambers, to the increased peripheral resistance. It may be assumed that the increase in SV in the 20th s of compression, in the absence of changes in HR or with some tendency toward bradycardia, is due to increased delivery of blood to the heart as a result of increased venous return at this time. It should be noted that, using the method of dilution of radioactive tracer, we determined in several subjects the volume of blood in the vascular region of the lower limbs (from the foot to the upper third of the thigh), and it constituted a mean of 1000 mℓ. With production of pressure in the "crural" and "thigh" chambers of the AGS, about 600-700 mℓ of blood shifted to the upper body. If we consider all of the foregoing, we see that there is a consistent increase in cardiac activity in the 20th s of compression. As for the slight decrease in TPR, it may be assumed that this reaction is caused by the increased capacity of the vascular bed in response to shifting of blood in a cranial direction, as a result of vascular occlusion in the lower extremities and elevation of intraabdominal pressure. Interestingly enough, A. G. Kartseva [10] found similar changes,

in the form of diminished TPR with increased MV and SV, as well as relative bradycardia, in studies involving ligation of the abdominal artery of animals.

Under conditions of constant pressure in the AGS chambers, the gradual relative decrease of SV and MV can apparently be considered a manifestation of compensatory reaction of the body to increased delivery of blood to the heart, great vessels and peripheral vascular system as a result of redistribution of blood. Marked flushing and some puffiness of the torso, upper extremities and face of the subjects are among the objective signs of plethora of the peripheral vascular system. The decrease in SV is apparently the decisive factor in the tendency toward poorer function of the heart, which is observed at this time.

The nature of changes in main hemodynamic parameters in the aftereffect period is determined by the increase in capacity of peripheral vessels and decrease in TPR with removal pressure from the AGS chambers. The decrease in peripheral vascular resistance causes a drop of AP and an increase of HR. The degree of decrease in TPR is determined not only by discontinuation of mechanical compression of vessels, but reactive hyperemia in the compressed areas [2].

Thus, the change in the set of hemodynamic parameters indicates that the greatest shifts are observed immediately after creating and immediately after removing mechanical compression. At the same time, in the course of such compression, there is some tendency toward recovery of the base volumetric characteristics of circulation, which can apparently be considered a manifestation of compensatory reactions in response to mechanical compression of the lower body.

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AUTOMATIC CONTROL OF GAS EXCHANGE IN THE AUTOTROPHIC COMPONENT OF A LIFE SUPPORT SYSTEM FOR HETEROTROPHIC ORGANISMS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 5, 1980 pp 73-77

[Article by V. L. Korbut, submitted 25 Oct 78]

[English abstract from source]

The paper describes an automatic gas exchange control system for the autotrophic component in the life support system of heterotrophic organisms. The paper shows how the automatic control system of the autotrophic component (wheat) can be combined with that of the heterotrophic component (four white rats). The study has demonstrated a high efficiency of the automatic gas exchange control system of plants integrated with animals. The study has also provided balance characteristics of the integrated gas exchange in the plant-animal system.

[Text] The task of controlling gas exchange of the autotrophic component with variable load, as dictated by the requirements of organisms that are elements of the heterotrophic component, is quite important to the life support system (LSS) that contains an autotrophic component to provide oxygen and utilize carbon dioxide of heterotrophic organisms (including man).

The need for continuous control of gas exchange of the autotrophic component when it is combined with a heterotrophic one is due to the biological variability of different specimens of these components in the course of their growth and development, changes in mass exchange and reactions to possible environmental factors that could lead to significant fluctuations in uptake (output) of O_2 and CO_2. Moreover, the gas exchange coefficients, $K = CO_2/O_2$, of autotrophs and heterotrophs do not coincide, which leads to continuous increase or decrease in concentration of one of the chief elements (CO_2 or O_2) of gas exchange therein [1, 2]. These causes prompted us to develop a special system for automatic control of gas exchange when the autotrophic and heterotrophic components of an LSS are connected.

Methods

We used wheat grown in a sealed phytotron as the model of the autotrophic element. The heterotrophic element was modeled by four albino rats put into a special airtight chamber (AC) that was equipped with special gates to replenish the supply of feed and remove excrements.

An automatic control system, the functional block diagram of which is shown in Figure 1, was developed to implement control of gas exchange in the plant--animal system.

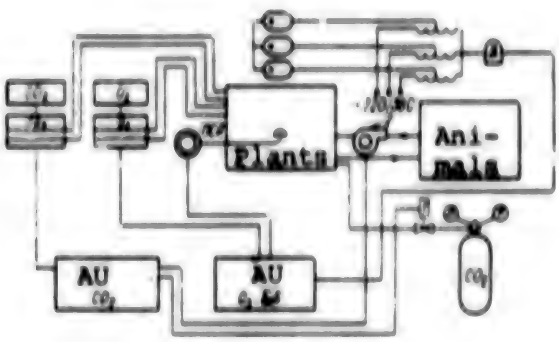

Figure 1.
Functional block diagram of automatic control of gas exchange in plant--animal system

1) electric valve
2) blower
ПКР) operating relay?
Д) pickup [sensor]
AU) automatic [control?] unit

An URAS-2 carbon dioxide gas analyzer maintains the CO_2 concentration in the phytotron in the specified minimum range of 0.31 vol.%. Upon reaching the specified lower range of CO_2 concentration in the phytotron, with the "min" setting on the secondary instrument of the gas analyzer the blower is turned on, which blows air through the gas exchange phytotron--AC--phytotron system, as a result of which there is equalization of concentrations of CO_2 and O_2, the O_2 concentration in the phytotron dropping and CO_2 concentration rising, while in the AC the concentration of O_2 increases and CO_2 decreases. The top range of CO_2 concentration in the phytotron was not regulated, and it depended entirely on gas exchange in the animals. We determined the intensity of gas exchange in the animals on the basis of increase in CO_2 in the phytotron after blowing air through the AC. If the concentration of CO_2 in the phytotron was less than the set minimum level after using the blower, delivery of a fixed dose of CO_2 from a tank was automatically triggered. The concentration of O_2 in the overall gas exchange circuit of the plant--animal system was regulated by changing the O_2 productivity of the plants. With increase in O_2 concentration above the set level (21.0 vol.%), there was automatic decrease in level of exposure of the plants, and with decrease in O_2 concentration below the set level, there was automatic increase in exposure level. Two-step regulation of exposure of the plants made it possible to maintain the O_2 concentration with accuracy of 1.5÷2.0% on the Magnos gas analyzer scale.

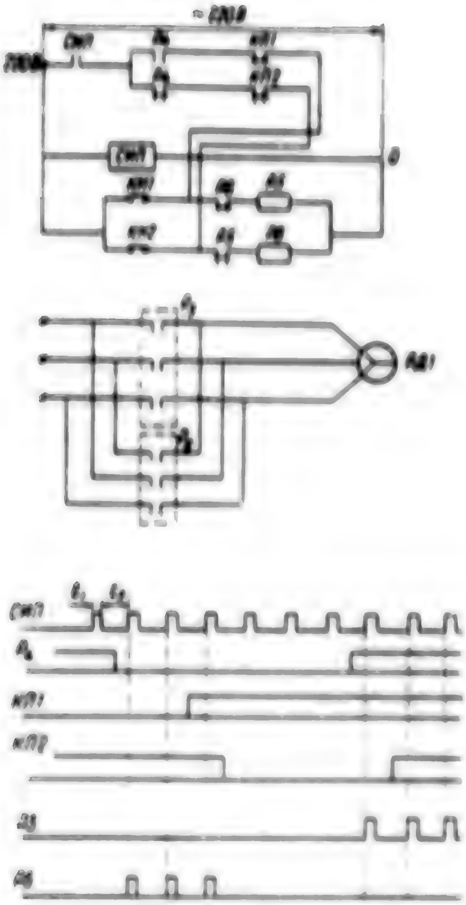

Figure 2.
Chart and time diagram of automatic stabilization of CO_2 concentration in plant--animal system.
pl) "min" CO_2 contact on secondary instrument of CO_2 gas analyzer

Upon reaching the set minimum CO_2 concentration (Figure 2), contact P1 is closed, which turns on auxiliary relay P2 and time relay PB1. If relay P2 had not been on previously and more than τ_2 has elapsed after operation of P1, power is delivered through closed contacts PB1, PB2 and P3 to the electric valve (ЭК) which, when it is open, delivers a dose of CO_2 to the phytotron with the plants. After a fixed time τ_1, contact $PB1_1$ is released and shuts the ЭК. Contact $PB1_2$ is released, setting PB2 in the initial position and turning on P3, which is connected through contacts P3 and K4 to the power source, independently of contact $PB1_1$. Relay P3 blocks, through normally closed contacts, delivery of CO_2 into the phytotron from the tank. Time τ_1 is selected on the basis of passage through the ЭК of the CO_2 dose sufficient to increase its concentration in the phytotron by 0.01-0.02 vol.% and reliable release of contact P1. After contact P1 is released, $PB1_1$ is set back to its original position and $PB1_2$ is released, turning PB2 on, which operates after time τ_2 (1-2 min). Time τ_2 is needed to prevent false operation of the circuit in the event of unbalanced indication of CO_2 concentration in the phytotron.

When the CO_2 concentration in the phytotron reaches the set bottom range, relays P2, PB1 and PB2 operate in the same way as in the first case, and is not released, since the normally closed contact P3 is open, but the command electrical instrument (CEI) is turned on through contacts PB2, P2 and P3. After an interval τ_4, contact K1 is released, and it provides for the full cycle of CEI operation. Concurrently, there is release of contact K3 and the air pump, which provides for complete mixing of air in the phytotron and AC containing the animals, is turned on. After time τ_5, contact K2 is broken; it turns off PB1 and thereby rules out the possibility of it operating before the end of mixing air in the phytotron and AC containing the animals. The air pump operates until contact K3 is disconnected

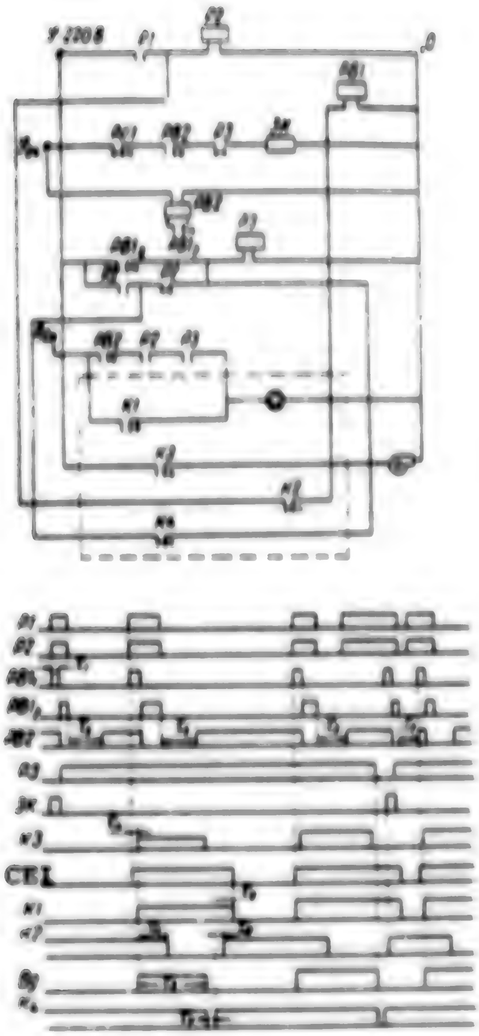

Figure 3.
Chart and time diagram of automatic control of O_2 plant productivity in a plant-animal system

after time τ_3, which is chosen on the basis of air pump output and three-fold air exchange in the AC. After the blower is turned off for a time τ_6 there is breaking of contact K4, and if the CO_2 concentration in the phytotron drops below the set level (normally closed contact P2 is open) the relay is turned off. After time τ_7, K2 closes, turning PB1 on, and after time τ_8, contact K1 opens. The CEI motor is stopped.

Thus, when P3 is turned off, the circuit operates as in the first case and with P3 on as in the second. Time lags τ_4, τ_6, τ_7 and τ_8 are selected as short as possible. Intervals τ_2, τ_3, τ_5, τ_6 and τ_7 must conform to $\tau_3 + \tau_6 + \tau_6 + \tau_7 \geq \tau_2$, which provides for actuation of PB2 by the time K2 closes. The system that regulates O_2 concentration (Figure 3) consists of a pulsed step switch [breaker] (СИП), O_2 concentration setter (relay P4), setters for maximum and minimum exposure of plants (relays КП1 and КП2), relays P5 and P6 that control the reversing motor (РД) of the autotransformer, which alters voltage to the DKSTV-6000 lamps. If the O_2 concentration in the phytotron drops below the set level, contact P4, which is normally open, is closed. The pulses pass through contact КП1 to P5 and РД increases the voltage of the lamps. Exposure of the plants increases and reaches the maximum set level, КП2 closes, while КП1 opens, and РД rotation stops. СИП is necessary to eliminate a lag between the change in irradiation of plants with change in voltage to the lamps and reading of irradiation sensor (Yanishevskiy pyranometer). The duration of СИП pulses was selected at $t_1 = 1$, with intervals of $t_2 = 14$ s. Switching on the normally closed contacts P5 and P6 precludes simultaneous operation of relays P5 and P6. Buttons KH1 and KH2 make it possible to control plant irradiation manually.

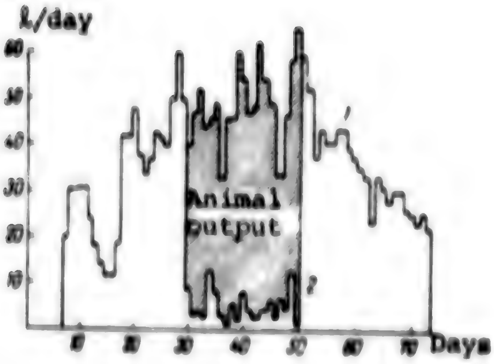

Figure 4.
Dynamics of gas exchange of wheat in a plant-animal system
1) plant CO_2 uptake curve
2) curve of delivery of CO_2 from the tank with automatic correction of its concentration in the system

The minimum level of irradiation (85 W/m^2 FAR [photosynthetically active radiation]) is selected so as to have the minimum O_2 uptake by the animals greater than output thereof by the plants. The maximum level of irradiation (275 W/m^2 FAR) is chosen so as to have O_2 output by the plants higher than uptake by the animals. Adherence to these conditions assures efficiency of the system for control gas animal and plant gas exchange.

Results and Discussion

Studies of plant and animal gas exchange were conducted by means of a specially developed automatic control system in the period between the 31st and 51st days of wheat vegetation. Figure 4 illustrates the curves of CO_2 exchange dynamics for wheat and animals. The balance characteristics of plant and animal gas exchange when contained in the same gas exchange circuit are listed in the Table.

Gas exchange of plants and animals contained in the same gas exchange circuit

Plant age, days	CO_2, ℓ/day			O_2, ℓ/day	AC = CO_2/O_2 of animals
	plant uptake	animal output	additional delivery	intake-output	
31	59.93	50.85	9.08	63.42	0.80
32	50.33	47.13	3.20	53.52	0.88
33	40.28	36.56	3.72	42.62	0.86
34	47.13	43.71	3.42	49.87	0.87
35	43.88	31.13	12.75	46.43	0.67
36	46.31	38.27	8.04	49.01	0.78
37	48.75	45.15	3.60	51.59	0.87
38	32.55	31.31	1.24	34.44	0.91
39	46.44	41.01	5.43	49.14	0.83
40	46.44	44.13	2.31	49.14	0.90
41	60.34	52.07	8.27	63.85	0.82
42	54.38	49.52	4.68	57.54	0.86
43	46.61	43.36	3.25	49.32	0.88
44	48.39	48.39	0	51.20	0.94
45	62.29	58.04	4.25	65.92	0.88
46	56.23	50.30	5.93	59.50	0.85
47	33.41	30.63	2.78	35.35	0.86
48	45.58	39.40	6.13	48.18	0.82
49	57.68	52.95	4.73	61.04	0.87
50	65.37	52.92	12.45	69.17	0.77
51	58.64	56.83	1.81	62.05	0.92
Over observation period	1050.91	943.66	107.25	1112.30	0.85±0.07

The submitted data indicate that the coefficient of gas exchange of animals in a system that is closed for gas exchange constitutes 0.85±0.07. There was automatic regulation of frequency of blowing air through the chamber with rate (3-4 times per hour). During the time of operation of the closed system, the wheat plants put out 1112.30 ℓ O_2 and took up 1050.91 ℓ CO_2 (943.66 ℓ output from the animals' breathing and 107.25 ℓ delivered into the system from the tank). Thus, in an O_2-balanced closed system, with a gas exchange coefficient of 0.95 for the plants and 0.85 for the animals, the CO_2 content will decline at a rate of about 10% of O_2 output (or intake). When plants and animals were contained in the same gas system, the mean concentration of CO_2 in the phytotron with plants was held at 0.31±0.02 vol.% and mean O_2 concentration at 21.0±0.02 vol.%. In the course of keeping plants and animals in the same gas exchange system, there was a 3-fold exchange of oxygen in the closed system by the 18th day, after which the animals' respiration occurred entirely at the expense of O_2 of biogenous origin, liberated from plant photosynthesis. By the time the experiment was terminated, O_2 exchange in the atmosphere of the closed system constituted 3.73-fold, and for CO_2 it was 239-fold. Vital functions of the animals and plants proceeded normally, and the animals' weight increased from 200 to 280-300 g. The grain yield by the end of the vegetation period constituted 1012.8 g/m^2 dry substance, which is consistent with data in the literature pertaining to growing wheat plants under artificial conditions [3].

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METHODS

UDC: 613.34-07-71

USE OF 'ULTRAVIOLET' INSTRUMENT FOR MONITORING THE QUALITY OF RECLAIMED DRINKING WATER

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 5, 1980 pp 77-79

[Article by S. V. Chizhov, Yu. Ye. Sinyak, M. I. Shikina and T. D. Kalinichenko, submitted 15 May 78]

[Text] One of the most important tasks in developing life support systems during space flights is to devise methods for ongoing monitoring of the quality of potable water reclaimed from waste.

It is known that impurities inherent in the initial products may get into reclaimed water intended for drinking in concentrations that are hazardous to human health if there is infraction of the technological conditions or depletion of the treatment system's resources. First of all, the impurities of organic origin present a hazard (alcohols, acids, hydrocarbons and others) [1], the most efficient monitoring of which is done by the luminescence method and the method of measuring total carbon [2-5].

Our objective here was to explore the possibility of using the luminescence method for ongoing monitoring of the quality of drinking water reclaimed from the condensate of atmospheric moisture (CAM) and obtained from dissociation of hydrogen peroxide.

Methods

The property of a mixture of complex organic substances to fluoresce, as well as the capacity of simple organic compounds (alcohols, acids, etc.) to quench the fluorescence of uranyl sulfate [6] served as the basis of our work. We used the semiautomatic Ultraviolet fluorimeter. An SVD-120 lamp, with an UFS-1 light filter, served as the source of excitation. The spectra of the substances inherent fluorescence were recorded on an SDL-1 spectrophotometer. Concurrently, blood samples were analyzed for organic admixture content by the methods of bichromate oxidizability [7] and chromatography for the purpose of making comparisons and determining the threshold values obtained by the tested method. We examined the sensitivity of the instrument to the most elementary alcohols and acids, which are primarily

liable to get into the reclaimed water. For this purpose, we tested model solutions in the range of concentrations from 10^{-1} to 10^{-5}%.

We examined the effects of construction materials used in the reclamation system on sensitivity and accuracy of instrument readings. We used ion exchange resins of the KU-2-12P, KU-2-8chs, AV-17-10P, AV-17-8chs types, PAU-SV, SKT-SV activated charcoal, polyvinyl formal foam (PVFF), an SP-6 sterilizer and MP-16 mineralizer. After the resins and charcoal, we first passed distilled water, then a CAM substitute (chemical oxygen index--COI--250 mg/ℓ) through the PVFF, SP-6, MP-1--distilled water. We evaluated the quality of the water reclaimed from the CAM substitute and that obtained from dissociation of hydrogen peroxide, as well as from a real CAM.

Results and Discussion

The findings revealed that the sensitivity of the Ultraviolet instrument constituted 10^{-3}% for alcohols and 10^{-4}% for acids. When the obtained data were scaled to bichromate oxidizability, the sensitivity of the fluorescence Ultraviolet instrument conforms with the requirements of existing standards for reclaimed water according to this parameter.

Studies of construction materials revealed that, in the experiments with distilled water, the resins and charcoals of the tested brands had no effect on the readings (in millivolts) of the luminescence instrument. The intensity of luminescence of filtrates was in the range of 2-3 mV. Upon sorption purification of the CAM substitute, gel-like ion-exchange resins imparted luminescence to reclaimed water, and it did not disappear when the water was filtered through activated charcoal. Such a phenomenon was not observed with the use of porous ion exchange resins. Upon contact of gel-like ion exchange resins with CAM, apparently a complex process occurs: migration of organic compounds from resin into liquid. This conclusion can be derived from the results obtained previously, when the luminescence method was used to assess the quality of a water extract from gel-like resins [3]. This finding is very important to water reclamation systems that work intermittently. When resins remain in liquid for a long time, impurities are discharged that have considerable fluorescnece of their own and that may be toxic. However, there was insignificant change in bichromate oxidizability of these solutions. An extract of PVFF with COI of 20 mg/ℓ after sorption purification presented its own luminescence, which coincided with the range of fluorescence of distilled water (less than 3 mV) and did not hinder determination of degree of purity of water.

As a result of discharge of silver ions in concentrations of 2 mg/ℓ into distilled water, the SP-6 sterilizer imparted luminescent properties to it and hindered determination of its purity; the intensity of fluorescence of the filtrates was in the range of 5-7.5 mV.

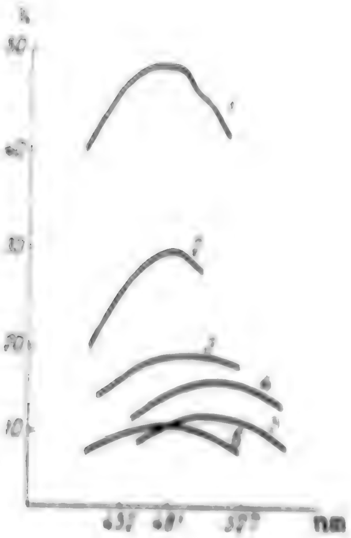

Figure 1.
Spectra of intrinsic fluorescence; x-axis, wavelength (nm); y-axis, fluorescence (relative units, %)
1) CAM with COI of 400 mg O_2/ℓ
2) urine filtrate after establishment of low-temperature evaporation, COI 260 mg/ℓ
3) condensate of hydrogen peroxide
4,5) water reclaimed from CAM, COI 50 and 25 mg/ℓ, respectively
6) distilled water

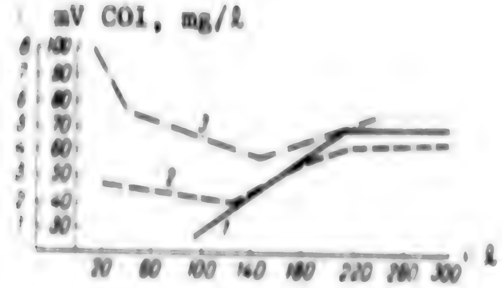

Figure 2.
Changes in COI and fluorescence during the process of CAM reclamation; y-axis, volume of reclaimed water (ℓ); y-axis, readings on Ultraviolet instrument (mV) and COI (mg/ℓ)
1) COI (mg/ℓ)
2) intensity of fluorescence in the presence of uranyl sulfate
3) intensity of intrinsic fluorescence

The MP-16 mineralizer discharged calcium and magnesium salts into water, which caused the water to fluoresce at an intensity of 3-4 mV. Thus, it was established that it is desirable to locate the instrument for monitoring the quality of reclaimed water after the unit of treatment columns and before the unit for conditioning [grading?] the water.

The results of analyzing water during reclamation from CAM and a mixture of products are illustrated in Figures 1 and 2. Figure 1 shows the spectra of intrinsic fluorescence of the tested products. The CAM has an intensity of 30-50%, which corresponds to 5-7 mV on the Ultraviolet instrument. The spectrum maximum is in the range of 480-500 nm. The spectrum of inherent fluorescence of samples of pure reclaimed water (COI less than or equal to 50 mg/ℓ) was significantly smaller than the intensity--15-20 relative units, which corresponded to 2-3 mV on the instrument. The intensity of the spectrum of intrinsic fluorescence of distilled water did not exceed 15 relative units. In the course of reclamation, the intensity of intrinsic fluorescence changed insignificantly at first, and did not exceed 3 mV. With increase in COI to 50 mg/ℓ or more, the intensity of intrinsic fluorescence began to increase, reaching 5-7 mV in some cases. With addition of uranyl sulfate into samples of reclaimed water we observed a decrease in fluorescence, from 8 to 4 mV on the Ultraviolet instrument, with increase in value of COI from 10 to 45 mg/ℓ.

According to the results of chromatographic analysis, methanol, ethanol and acetic acid, which quench the fluorescence of uranyl sulfate, get into reclaimed water. When more complex organic compounds inherent in the original product (acetaldehyde, acetone, butanol, propanol and others) got into reclaimed water, there was an increase in COI and intensity of fluorescence of filtrate with uranyl sulfate. There was superposition of the enhanced intrinsic fluorescence over that of uranyl sulfate. Identical results were obtained with the CAM substitute and the real product.

Analysis of the results of assessing water reclaimed from a mixture of condensate of atmospheric moisture and water obtained from dissociation of hydrogen peroxide failed to demonstrate any basic differences from the findings in studies of water reclaimed from CAM. The intensity of intrinsic fluorescence of water obtained from dissociation of hydrogen peroxide corresponded to 15% and did not affect fluorescence of the CAM.

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CHOICE OF METHOD FOR LONG-TERM STORAGE OF NUTRIENT SOLUTIONS USED TO GROW VEGETABLES

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 5, 1980 pp 79-81

[Article by I. V. Gribovskaya, I. A. Gladchenko, O. I. Novoselova, G. S. Petrov and L. L. Martynenko, submitted 9 Oct 79]

[Text] There are specific elements to raising higher plants under space flight conditions, as compared to cultivation thereof under artificial conditions in phytotrons on the ground. The nutrient medium used must not have to be replaced, and there must be automatic control of biogenic constituents and pH by means of addition of nutrient solution supplements. At the same time, the nutrient solution must withstand long-term storage in concentrated form, in containers of limited size. The materials used to construct phytotrons and containers for nutrient solutions must not weigh much ["must not have high specific gravity"] or interact actively with the medium to avoid significant changes in pH as time passes, precipitation of sediment and additional discharge of elements into the environment. Questions of nutrition of higher plants in ground-based phytotrons have been discussed rather comprehensively in the literature [1-4]; however, there has not been adequate solution of this problem for space flight conditions [5]. There are works that deal with materials used in cultivators and phytotrons [6-7]. However, this does not preclude the need for additional studies to select construction materials for each specific case.

The objective of such studies includes the following: choice of conditions that permit storage of nutrient solution for 3 months in a stable state, without sediment, and with maximum possible concentrations of constituents; testing the construction materials used for corrosion, possible changes in solution pH, precipitation of a saline sediment, for sorptive and desorptive properties of materials with regard to minerals.

Methods

Studies were made with balanced, concentrated nutrient solution of the following composition: 80.5 g KNO_3, 46 g $Ca(NO_3)_2 \cdot 4H_2O$, 1 g HNO_3, 14.1 g

KH_2PO_4; 3 g H_2SO_4 and 17.8 g $MgSO_4 \cdot 7H_2$. To the solution we added 0.03 mℓ iron citrate, 12 mℓ solution of trace elements according to the prescription of Knop, 0.4 g Trilon B. The construction materials intended for use in the phytotron during space flights are listed (Table 1).

Table 1. Characteristics of tested construction materials

Material	Brand	Proposed use
Metal	OT-4	Containers for nutrient solutions
Untreated (sheet) aluminum alloy	AMg6	Same
Electrochemically oxidized aluminum alloy	AMg6	Same
Sheet rubber (0.3 mm thick)		Membranes
Rubber ring	Ml-14×8-2	Gaskets
Hot water bag rubber		Flexible containers for diluted nutrient solution

With respect to quantity, the proposed nutrient solution provides for growing 7 kg crude biomass of radishes by the subirrigation method over the vegetation period (24 days) per square meter; 4 kg radish biomass was referable to the root crop (228 g dry mass) and 3 kg to the leaves (204 g dry mass). The estimated intensity of continuous irradiation of the plants constituted 80 W/m^2. All of the tests with nutrient solution in contact with the materials and without them were conducted in glass flasks at room temperature. The tested salts (Table 1) were dissolved in 200, 400, 600, 800 and 1000 mℓ distilled water and stored for 3 months. Throughout the study period we monitored (once a week) changes in pH, appearance of saline sediment and signs of corrosion.

The method for using the tested concentrated nutrient solution to grow radishes in a spacecraft or station provides for long-term storage thereof in metal containers. At the time the phytotron is started up, half of the stored concentrated nutrient solution of the proposed composition must be delivered into elastic containers and diluted in distilled water to a volume of 2 ℓ. Delivery of the nutrient solution from the rubber bags to the cultivator proceeds automatically through a batcher, when there is a change in solution pH (normally pH is 6.0-6.7).

Results and Discussion

Our results revealed that the complete set of salts of the nutrient solution cannot be stored in amounts of 1 liter or less, since the salts form a sediment as early as the first week of the experiment. It is not expedient to increase the volume of nutrient solution to 3 ℓ or more under space flight conditions. For this reason, we decided to divide the solution into two parts. This enabled us to reduce the overall volume and,

consequently, the mass of solutions, as well as to extend significantly storage time (Table 2).

Table 2. Chemical composition of constituents of nutrient solutions

Composition	Amount, g	Composition	Amount, g
KNO_3	80.5	KH_2PO_4	14.1
$Ca(NO_3)_2 \cdot 4H_2O$	46.0	$MgSO_4 \cdot 7H_2O$	17.8
HNO_3	1.0	H_2SO_4	3.0
Fe (in citrate form, 50 g/ℓ)	6.6	Trace element solution	12
Trilon B	0.2	Trilon B	0.2

*Given in milliliters [asterisk not shown in table].

The tests with the first solution revealed that 400 mℓ is the smallest amount, in which all of its constituents can be stored in a stable state for a long time, without change in pH. A sediment is precipitated if it is stored in smaller amounts (300, 200 mℓ).

The conditions for preparing the solutions provided for successive dissolution of salts in small batches, in distilled water heated to 50-60°C. The solution of iron citrate was added last. To increase solubility of the salts, we added 1-2 mℓ HCl, pH 0.5-1.0, for every 400 mℓ solution.

The second solution can be stored in a glass flask for a long time in amounts of at least 600 mℓ. It was prepared in the same way as the first solution (pH 1.6-1.8).

Contact with the tested materials did not always affect storage of nutrient solutions in the same way. In the presence of Ti, sheet rubber and the rubber ring, solution No 1, in a volume of 400 mℓ, did not change its properties for the duration of the experiment. In solution No 2, in a volume of 600 mℓ, a saline sediment appeared and solution pH changed in the presence of the above-mentioned materials; storage thereof with these materials can be guaranteed for 3 months only if the volume is increased to 800 mℓ.

Treated and untreated aluminum alloys AMg6 were found to be the most unstable of the tested materials with regard to interaction with nutrient solutions. In the first solution, in an amount of 400 mℓ, pH changed from 0.7 to 3.59 in the presence of AMg6 during the experimental period (3 months), and in the second solution, in a volume of 800 mℓ, it changed from 1.7 to 2.4; a saline sediment appeared on the 5th-7th and 2d-3d weeks of the experiment, respectively. Increasing the volume of the second solution to 1-2 ℓ in the presence of the AMg6 alloy merely postponed appearance of the salt sediment by 1-2 weeks. Formation of the sediment was preceded by appearance of a black oxide film on the metal, which came off the metal in flakes when the solution was shaken, and then formed again upon further storage of the solution. By the end of the experiment, the metal had a

rough corroded surface. The treated AMg6 alloy had no appreciable advantages over the untreated one; when interacting with the solution there was always formation of the oxide film on the metal, as well as a salt sediment, with some change in time of appearance of these signs, depending on the rate of change in solution pH.

The hot water bottle rubber was tested in diluted nutrient solutions (solution No 1 was diluted 10-fold and No 2 5-fold). During the 3-month experiment no salt deposits were demonstrable, but pH changed from 2.0 to 5.0-6.0 at the end of the test. At the same time, there was active development of microscopic fungi in solutions that were in contact with this rubber.

As a result of comparative spectral analysis of nutrient solutions with and without materials, it was found that metals have essentially desorptive properties. The Ti sheet discharged only one element into the first solution, Ti in amounts of 0.058% (provided there was 2 cm^2 metal surface per 100 mℓ solution). The sheet AMg6 alloy had the greatest desorptive properties (3 cm^2 metal surface per 100 mℓ solution, associated with emission of Al, Mn, Fe, Cr, Ni, Ti, Cu in the following amounts (in mg%): 300, 0.8, 37, traces, traces, traces, 0.2, respectively, in solution No 1, and 70, 6.0, 1.0, 0.06, 0.07, 0.1, 0.2 in solution No 2.

As can be seen, the quantitative and qualitative composition of elements released by the materials were related to the composition of the solution and its pH. Soluion No 1 had a lower pH than No 2--0.7 and 1.7, respectively. Considerably more Al, Fe and Cu, but less Cr, Ni and Ti were discharged into solution No 1 than solution 2. It must be noted that the figures cited for the treated AMg6 alloy are 10-12% for most elements than for the untreated alloy. There are differences in Ni content: Ni was discharged in amounts of 0.07 mg% from treated AMg6 into solution No 2, whereas only trace amounts were released from untreated allow. There was desorption of Zn, Cu, Al, Pb and Ni from the rubber of hot water bottles in solution No 2, with sorption on its surface of Fe, Mn and B.

All of the tested construction materials had not been used prior to our experiment. However, it must be borne in mind that the desorptive properties of both metals and other materials diminish in the course of repeated use. The change in desorptive properties of materials as a function of time, pH, temperature and treatment of materials was described by us previously [6], and we had demonstrated that there was a 2-5-fold decrease in emission of elements from materials into solution over a 2-month test period. Consequently, prior to the use of a newly constructed device, all parts thereof that come in contact with nutrient solutions must be submitted to preliminary treatment in order to lower the desorption level.

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METHOD FOR PRODUCING CLINOSTATIC HYPOKINESIA IN MONKEYS

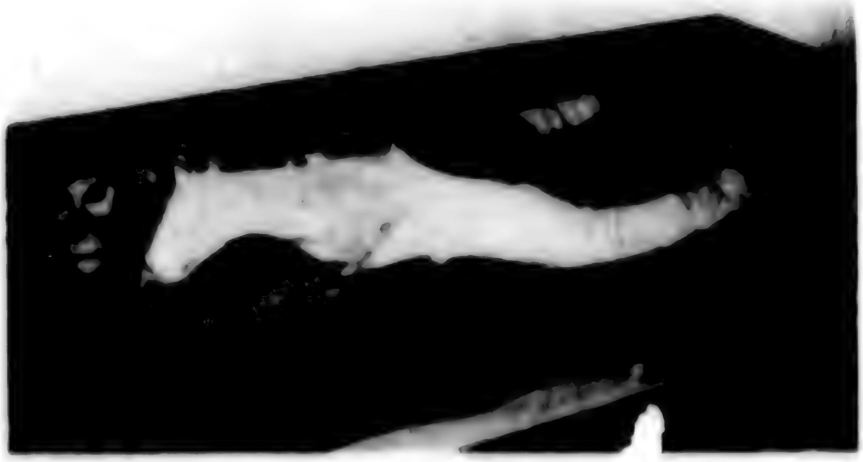
Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 5, 1980 pp 82-84

[Article by T. G. Urmancheyeva and A. A. Dzhokua, submitted 14 Nov 79]

[Text] One can achieve some degree of restriction of movement by monkeys by keeping them in primatological chairs, which are widely used in experiments for partial immobilization of animals [1]. It has been demonstrated that keeping monkeys in a primatological chair for a long time (4 weeks to 2 years) does not have an adverse effect on their physiological state [2, 3]. Long-term immobilization of different extremities by means of metal straps was used for the study of morphological, biochemical and physiological changes in the skeletal muscles of lower monkeys [4]. A special suspension device has been described for immobilization of marmosets with rigid, plastic bars ["tires"?] [5]. During flights over a ballistic curve, monkeys were immobilized with a tightly fitting sheath in a rigid metal frame [6]. D. Kh. Born and M. N. Golarts de Born [7] placed Macaca rhesus monkeys in rigid porous suits, leaving the hands and feet free, to restrict the activity thereof in horizontal position.

Methods

We tested a method of producing clinostatic hypokinesia in monkeys by means of special overalls. The monkeys (Macaca rhesus) were restricted by these overalls, which buttoned in the back and had an opening in the perineal region. Over the entire length of the suit, from the arm-hole to the ankle joint, pairs of tapes were stitched into the side seams at a certain distance from one another. These tapes are passed through openings that were made in canvas-covered cot (wooden frame, 110×50×70 cm in size) and tie the overalls to the cot (see Figure). With such immobilization, the animal's legs are extended in the hip and knee joints. It retains freedom of movement in all of the arm articulations and in the ankles. The monkey was turned from back to abdomen periodically, every 2-3 days. An intact monkey (Macaca rhesus, No 15858, 3 years old, weight 3.6 kg) was kept immobilized under the above-described conditions for 45 days.



Macaca rhesus immobilized in horizontal position (prone) on cot

Throughout the period of hypokinesia we measured the monkey's arterial pressure (according to Korotkov) twice a day. We recorded the EKG at different stages of the experiment with the animal in both supine and prone positions, in the standard and chest leads. We kept a log of the animal's general behavior and attitude toward food daily, during the 45 days of hypokinesia. Immediately after termination of the experiment, we tested orthostatic stability by means of a passive orthostatic test (on a small turntable) using a method developed by G. S. Belkaniya [8]. During the orthostatic test, we measured arterial pressure and took the EKG in the standard leads, in horizontal and vertical position, then after 5, 10, 15 and 20 min of orthostatic position.

Results and Discussion

During the first hours of immobilization in horizontal position, the monkey presented severe motor excitation related to attempts at freeing itself; there were vocal reactions and elevation of arterial pressure (AP) to 140/80 mm Hg. However, the animal calmed down as yearly as 6 h after immobilization and AP dropped to base levels (120/60 mm Hg); the monkey ate willingly from the experimenter's hand. Throughout the period of hypokinesia, the animal was approachable, reacting adequately to the surroundings and experimenter. We failed to detect any changes in the animal's attitude toward food throughout the experiment, with the exception of the first 2 weeks, when it often refused water and other liquid forms of food.

In the course of the experiment, AP ranged from 115-125/60-65 to 130/75 mm Hg, i.e., it was in the physiological range. EKG's taken at different stages of immobilization failed to demonstrate reliable changes in pulse rate or quantitative changes, as compared to base data with the monkey in prone position. In supine position, sinus arrhythmia developed on the 2d-6th days. The EKG showed slowing of the pulse.

During the 45 days of hypokinesia, the monkey's weight dropped from 3.6 to 3.0 kg, i.e., by 17%. In this time, animals of the same age group showed a weight gain of 5-11%. The circumference of the legs decreased from 11.7 to 9.0 cm by the end of the experiment (see Table). The observed decrease in weight and circumference of the lower extremities conformed with findings referable to long-term immobilization of man and animals [9-12].

Dynamics of changes in body weight and leg circumference of the monkey after 45-day hypokinesia and during the readaptation period

Parameter	Base data	Hypokin. (45th day)	Recovery period, days							
			1-й	8-й	12-й	18-й	22-й	27-й	36-й	48-й
Body weight, kg	3.6	3.0	2.9	2.8	2.6	3.0	3.2	3.2	3.5	3.6
Circumference of leg, cm	11.7	9.0	9.3	9.8	10.2	10.9	11.2	11.7	11.7	—

The orthostatic test conducted after 45 days of hypokinesia revealed shortening of the period of the primary vascular reaction to 10 min, after which, in the 15th min, there was development of progressive orthostatic hypotension. The changes in cardiac rhythm were not marked during this test and, along with the nature of the primary AP reaction, were indicative of diminished orthostatic stability.

The monkey presented signs of adynamia after hypokinesia: motor activity was diminished, as compared to its usual behavior. There were distinct disturbances referable to locomotion, running and climbing. When moving over the floor of the cage, the monkey dragged its hind legs. When climbing, the legs slipped off the screening, the movements were broad and inaccurate. Impaired flexion of the hind legs, diminished locomotor reaction and ataxia persisted for 2 weeks of the readaptation period. Concurrently, there was palpable decrease in muscle tone of the lower limbs. In this period the monkey continued to lose weight (from 3.0 to 2.6 kg).

The leg circumference reverted to its initial size only 27 days after the experiment. Body weight was restored only by the 48th day of readaptation (see Table).

On the whole, the disturbances that developed (weight loss, decreased volume and tonus of muscles of the lower extremities, statokinetic disturbances) and dynamics thereof in the readaptation period were similar to those seen in man submitted to long-term clinostatic hypokinesia [13-16].

Consequently, the method we developed for immobilizing and keeping monkeys in horizontal position for a long time can be used to simulate the effects of clinostatic hypokinesia on these animals.

The described method has already been used at the Institute of Experimental Pathology and Therapy of the USSR Academy of Medical Sciences in a 32-day experiment on 5 monkeys (Macaca rhesus) to study the effects of clinostatic hypokinesia on adrenal and gonadal functions.

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DISCUSSIONS

UDC: 613.693:612.821]:658.311.44

CERTAIN PERSONALITY CHARACTERISTICS AS RELATED TO SUCCESS OF PILOT TRAINING

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 5, 1980 pp 84-87

[Article by Ye. V. Bannov and V. S. Lozinskiy, submitted 31 Aug 79]

[Text] Psychological screening of candidates for flying schools is one of the aspects of solving the problem of effective and safe flights. At the present time, much importance is attributed to complex examination of individual psychological distinctions of candidates in professional screening for higher flying schools.

Studies are made not only of the main mental processes, but of personality traits and mental states.

Personality methods are being introduced into the practical psychological screening of candidates for flying schools in accordance with the studies of B. L. Pokrovskiy and N. F. Luk'yanova [1, 2].

We have studied here the overall correlation between measured personality traits and such indicators of achievement in flight training of cadets as level of development of the main mental processes, flying skills [abilities], training and check-out [test] flying hours in basic flight training.

Methods

In the course of this study, we examined cadets at a higher flying school using the MMPj method [3] and 16-factor analysis of the personality [4]. Along with personality tests, we held individual conversations in order to study personality distinctions, states and to define the test results obtained with the personality methods.

We also used data referable to observations during psychological screening and training of the cadets at the school. In all, we surveyed 1044 cadets. They were questioned and examined at the time of enrollment at the school and after completing the first, second, third and fourth courses.* A total of 2662 examinations were made by the method in [3] and 2918 interrogations by the method in [4]; we held 1118 conversations and gathered more than

*"Course" probably refers to year [translator's note].

9000 ratings of the cadets' achievement. The obtained data were submitted to statistical processing on a computer. In the group of cadets who were the best in flying achievment and individuals who had difficulty in assimilating the flight program, we determined the following parameters: arithmetic means of 33 personality traits and 6 parameters of an external criterion (level of development of the main mental processes, flying skills, capabilities, training and check-out runs, number of flights and time); mean square deviation of parameters; coefficient equaling the ratio of mean arithmetic to standard deviation; mean error of mean values; reliability of differences between compared parameters; coefficient of correlation between the parameters studied. We derived averaged profiles for the compared groups and determined significant correlations between the parameters studied.

Results and Discussion

Figures 1 and 2 illustrate the averaged profiles of candidates who were the best achievers and individuals who had difficulties in assimilating the flight program.

Analysis of the averaged data enabled us to demonstrate a number of basic personality traits inherent in both the good and poor cadets.

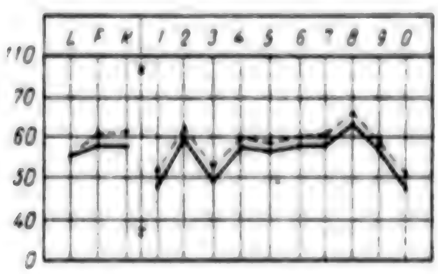

Figure 1.
Averaged data by the MMPj method for candidates with good flying skills (solid line) and those experiencing difficulties in assimilating the flight program (dash line)

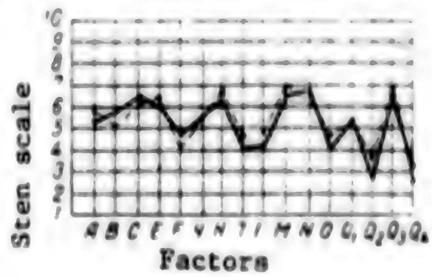

Figure 2.
Averaged data from the 16-factor personality questionnaire for cadets with good flight skills (solid line) and those experiencing difficulties in assimilating the flight program (dash line)

The personality traits of good and poor cadets are characterized by such distinctions as activity, vigor, sociability, self-confidence, decisiveness, courage, purposefulness, well-developed sense of duty, responsibility, vivid emotionality with a high degree of self-control. At the same time, there are some personality traits that are inherent in representatives of either group.

Thus, the profiles of the poor achievers were characterized primarily by an increase in values on scales 1, 3, 4, 6, 7 and 8 of the MMPj (L, F, K--scales for determining the reliability of test performance; 1--degree of fixation on one's health; 2--tendency toward agitation, control of emotions; 3--emotional lability, social flexibility, conformity; 4--tendency to take risks, impulsiveness, high level of pretentiousness; 5--masculine and feminine personality traits, orientation of sexual interests; 6--rigidity of judgments, "hardness" of sets, persistence, stubbornness; 7--anxiety, psychasthenic features; 8--uniqueness of thinking and perception, intuitiveness; 9--level of activity and optimism; 0--social introversion--extroversion). A statistically reliable increase in levels was noted on scales 3, 4, 7 and 8. These cadets were more willful, restless, excessively self-confident, emotionally immature, argumentative, adjusted poorly to the group, notable for demonstrative nonconformity, increased impulsiveness and inadequate self-control over emotions.

According to the 16-factor questionnaire, the group of achievers differed from the poor achievers in that they presented higher factors B (intellect), C (emotional stability), F, N, Q_4 and lower A, E, H, 1, 1, M, O, Q_2 (A--reserve--gregariousness; B--concrete thinking--abstract thinking; C--sensitivity--stability, rationality; E--compliance--domination; F--seriousness--cheerfulness; G--initiative--compliance; H--undecisiveness--desiciveness; i--emotional maturity, realistic--tendency toward fantasizing, refinement; l--trustfulness, adaptability--inflexibility, preference for one's own opinion; M--practicality--impracticality; N--ingenuousness--calculation; O--self-confidence--anxiety; Q_1--conservatism--innovativeness; Q_2--dependence on group--independence; Q_3--internal conflict--self-control; Q_4--relaxed calmness--high motivation). This shows that in the good achievers there was greater development of such characterological personality traits as practical approach to solving intellectual problems, self-criticism, emotional stability, social flexibility, good equilibrium, objectivity, decisiveness, courage and adequate self-control over emotions.

As a result of analyzing the profiles by the MMPj method of the good and poor achievers in flight training, we demonstrated an increase of this parameter on scales 2, 7 and 0 (along with slightly elevated 5 and 9) in 5.3% of those examined. Of these, the good achievers constituted 1.2% and poor achievers 1.8%. The cadets in these groups were characterized by a tendency toward anxious reactions, marked desire to avoid failure by increasing control of their actions, more thorough preparation for classes, tests, flights, they think out (run through, utter) elements of activity, they are industrious, compliant, conscientious, experience tension during flights, passive in social life, are notable for being suggestible, having a low opinion of themselves and limited range of socialization.

Elevation of the profile on scales 4, 6, 8 and 9 in different combinations, with increased scale 2, is encountered in 2.7% of the cadets surveyed (1.1% being referable to the best achievers and 0.8% to the poor ones). Cadets with this profile are notable for such characterological features as high level of incentives and activity, marked tendency toward competitiveness, large reserve of optimism, courage, bravery and a tendency to

take chances. These personality traits are combined with such elements as emotional immaturity, inadequate control over emotions, impulsiveness, stubbornness, excessive confidence in the accuracy of one's position, difficulty of interpersonal contacts and overestimation of one's own capabilities.

Correlations between measured personality traits and criteria of achievement of cadets in their flight training

Factor and scale	Level of developm. of main mental processes	Flying skills	Training and test flights, 1st course		Training and test flights, 3d course	
			flights	time	flights	time
A						
B	−0.24	−0.33	−0.55	−0.42	−0.32	−0.46
C	−0.51		−0.44	−0.17	−0.17	−0.11
E						
F			+0.09	−0.40	+0.07	−0.11
G			−0.19	−0.35	−0.16	−0.37
H			−0.21	−0.11	−0.13	−0.62
I			0.07	−0.30	−0.03	−0.01
L						
M	+0.33	−0.52	+0.41	+0.17	+0.09	0.32
N						
O	+0.50	−0.46	−0.37	−0.12	−0.56	−0.39
Q_1	−0.14		−042	−0.35	−0.44	−0.26
Q_2	+0.43	−0.40	+0.22	−0.02	−0.31	−0.08
Q_3						
Q_4		−0.30	+0.57	+0.44	−0.16	−0.49
F_1	−0.23	−0.13	+0.52	+0.40	+0.07	−0.37
F_2			−0.39	−0.05	−0.09	−0.14
F_3			−0.03	−0.02	−0.07	−0.33
F_4						
L	−0.42	−0.23				
F			+0.06	+0.25	+0.60	+0.31
K						
1	+0.30		+0.10	−0.19	−0.45	+0.48
2	+0.22		+0.09	+0.34	+0.02	+0.04
3	−0.27		+0.30	+0.38	+0.53	+0.10
4	+0.52		+0.04	+0.21	+0.14	+0.43
5			−0.11	−0.12	−0.11	−0.11
6			−0.07	+0.16	+0.40	−0.26
7			+0.22	+0.12	+0.55	+0.15
8	+0.30		+0.16	−0.55	−0.02	+0.02
9		−0.24	+0.60	+0.19	+0.36	+0.08
0	+0.27		+0.05	+0.10	+0.02	+0.25

About 90% of the cadets are characterized by elevated profiles on scales 4, 6, 8, 9 and 2, 5, 7, 0 in different combinations (19.1% being referable to good achievers and 16.3% to poor ones). The personality traits of these cadets are characterized by even temper, absence of any psychological problems or difficulties, confidence in their capabilities, high level of inducement, high self-appraisal, activity and sociability. These individuals are emotional, they are in good control of their emotions, adequately aggressive and decisive. They have a rather well-developed feeling of duty and responsibility.

Of the cadets surveyed, 2% have elevation of the profile on scales 1 and 3 combined with increased 6, 8 and 0. There were no good achievers among this group, and poor achievers constituted 0.2%.

The degree of correlation between all measured personality traits--33 parameters of personality traits (16-factor analysis of the personality and MMPj) and 6 parameters of the external criterion of achievement in cadet flight training was found to be significant in 10 cases (B, G, M, O, Q_1, Q_4, F_1, F, 3, 9). In eight cases (C, F, H, Q_2, 1, 4, 6, 7) there was mild overall correlation between the parameters studied (see Table).

The most reliable correlation was demonstrated between factors B and flight abilities, number of training and test flights in the 1st and 3d courses; between factor O and level of development of the main mental processes, flight skills, number of training and check flights in the 1st and 3d courses; between factor Q_4 and flight skills, number of training and test flights during the 1st course; between F_1 and flight abilities, number of training and check flights in the 1st course.

A reliable correlation was also demonstrated between external criteria and factors C, F, G, H, M, Q_1, Q_2 [4], scales 1, 3, 4, 6, 7, 9 [3].

The Table lists summary data on degree of correlation between the measured personality parameters and external criteria for rating flight achievement of the cadets.

As can be seen in this table, the level of development of the main mental processes, as determined in psychological screening of candidates for flying school, is correlated with factors B, C, M, O, Q_1, Q_2, F_1 [4] and scales 1, 1, 2, 3, 4, 8, 0 [3]. The cadets classified in group 1 in psychological screening are characterized by personality traits, in the profile of which there are high factors B, C, Q_1, whereas factors M, O, Q_2, F [4] and scales 1, 1, 2, 3, 4, 8, 0 [3] are lower than analogous parameters of cadets who were graded in group 3 by the psychological screening. The most reliable correlation is demonstrable between level of development of the main mental processes, factors C. M, O, Q_2 and scales 1 and 4.

The cadets with good flying skills were characterized by relative elevation of factor B and decline of factors M, O, Q_2, Q_4, F [4] and scales 1, 9 [3]. In individuals who made the fewest number of flights on the basic introductory program and tests presented elevation of factors B, C, G, H, Q_1, F_2, decline of M, O, Q_2, Q_4, F_1 and scales 3, 7, 9 of the profile.

According to the time spent on training and check-out flights in the 1st course, the best cadets presented elevation of factors B, G, Q_1, and decline of F, 1, Q_4, F_1 and scales F, 2, 3, 4, 8.

There was a close correlation between the number of training and test flights in the 3d course and factors B, O, Q_1, Q_2, and scales F, 1, 3, 6,

7, 9. For the best achievers, there was elevation of factors B, O, Q_1, Q_2, with relative decline of scales F, 1, 3, 6, 7, 9.

According to the time spent on introductory and check-out flights in the 3d course, the best achievers presented elevation of factors B, G, H, O, Q_1, Q_2, F_1, F_3, decline of factor M and relative decline of scales F, 1, 4, 6, 0.

Thus, the results of these studies warrant the statement that elevation of factors B, C, G and values of factors O (4 or less sten), M (5 or less sten), Q_2 (3 or less sten), scales 1, 1, 3 (50 T or less) and 9 (55 T).

Consequently, the well-achieving cadets are characterized by such personality traits as higher intelligence than poor achievers, emotional stability, rationality, decisiveness, conscientiousness, courage, broad interests, practicality, leadership, vigor, good control over behavior and emotions, sincerity.

The results of these tests define and correct the previously developed criteria of cadet personality traits with different levels of flying achievement,and they further refine psychological screening of candidates for higher flying schools.

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BIOASTRONAUTICS YESTERDAY, TODAY AND TOMORROW

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 5, 1980 pp 88-92

[Article by V. V. Budilovskiy and V. B. Pishchik, submitted 7 Apr 80]

[Text] In our times, cosmonautics is growing into an increasingly international branch of human endeavor. More and more countries are striving to participate in the exploration and utilization of space. For this reason, there has been a significant increase in volume of information shedding light on the stages of development of bioastronautics. In order to enable the readers of this journal to be regularly informed of such information, it was decided to add a section entitled "Bioastronautics yesterday, today and tomorrow," where surveys will be published with current information on the following topics:

1. Chronicles of bioastronautics.
   History of aerospace medicine (stages of development, noteworthy dates, personalities, anniversaries).
   International collaboration and exchange of information.
   National and international organizations.
   Congresses, conferences and symposiums.

2. Main directions of research.
   Research in the field of space medicine, space biology and biomedical technology.
   Provisions for life support conditions in and out of spacecraft.
   Screening, training and professional performance of cosmonauts.
   Medical back-up of space flights.
   Use of advances in space engineering, technology and medicine in the national economy and public health care.
3. Discussions, plans and forecasts.*

*The foregoing introduction was written by the editorial board, while the above-cited authors' article appears on the following pages [translator's note].

Fifteen Years Since Man Walked in Space

"--Zarya! I am Almaz. A man has gone out into space!" These words echoed over our planet 15 years ago, on 18 March 1965, at 1130 hours Moscow time. They were broadcast over the ether by Pavel Ivanovich Belyayev, commander of the Voskhod-2 spacecraft, at the very moment that the second crew member, Aleksey Arkhipovich Leonov, was taking a space walk wearing a special suit with an autonomous life support system (Figure 1).

Figure 1.
EVA by A. A. Leonov from Voskhod-2 spacecraft on 18 March 1965 [2]

On that day in March, Soviet science inscribed one more glorious page in the chronicles of the conquest of space.

Summing up the flight of Voskhod-2, Academician S. P. Korolev stated: "The crew was confronted with an extremely difficult task, of a very different quality than those of prior flights. Further development of cosmonautics depended on successful performance thereof, probably to the same extent as on the success of the first space flight. Pavel Belyayev and Aleksey Leonov coped with it, and it would be difficult to overestimate the significance of this feat...." [2].

Five Years Since the Apollo-Soyuz Test Project

On 15 July 1975, at 1520 hours Moscow time, Soyuz-19 spacecraft was launched from Baykonur, the Soviet spaceport, with cosmonauts A. A. Leonov and V. N. Kubasov aboard. Several hours later, Apollo spacecraft was launched from Cape Canaveral with astronauts T. Stafford, D. Slayton and W. Brand.

On 17 July at 1912 hours, the spacecraft docked and began a joint mission that lasted 2 days. In this time, the participants conducted five joint experiments, two of which dealt with biomedical problems of space flights. In the "Microbial exchange" experiment, a study was made of the conditions under which there was an exchange of microorganisms among the crews of different spacecraft. The "Zone-Forming Fungi" experiment was conducted to study the effects of space flight factors on the main biological [circadian] rhythms.

The successful mission accomplished by the Apollo-Soyuz test project was a historical contribution to the development of international collaboration in the exploration of space (Figure 2).

The commanders of Soyuz-19 and Apollo made the following statements during the flight:

A. A. Leonov: "This flight will become an important step on the endless road of exploration of space by the joint efforts of all mankind."

T. Stafford: "As we open the hatch into space, we are opening a new era in the history of mankind. How this era will develop in the future will depend on the will, efforts and faith of the people of both nations, the people of the entire world" [3].

Screening of French Cosmonauts for Flight Aboard the Salyut Station

The director of the French National Center for Space Research reported that 261 applications were received between the time of announcement (late October 1979) that French cosmonauts would be recruited to fly aboard the Soviet Salyut station and termination thereof (15 November 1979). Among the individuals who applied there were 50 servicemen and 37 women. A total of 70 people will be chosen on the basis of questionnaires and medical records to undergo various tests at the Space Center in Toulouse. By the middle of 1980, 2 candidates will have to be selected out of these 70 people, and they will undergo appropriate training in the USSR. One cosmonaut will be picked of these two candidates just prior to the flight (scheduled for 1982).

Figure 2. Commemorative medal in honor of ASTP, halves of which were taken aboard Soyuz-19 and Apollo and joined in space [3]

Preparations for Biomedical and Biotechnological Experiments in the Spacelab Laboratory

The bulk of the research and experiments dealing with bioastronauts, which have been scheduled for the next few years by western nations will be conducted during the flights aboard the American reusable space transport (MTKK), the "space shuttle" with the Spacelab laboratory on board.

The space shuttle is the main project in the national space program of the United States. Work on this project is close to completion: the first flight of the new craft will take place in late 1980 or early 1981. The space shuttle is the first generation of reusable transportation space systems, which was called the space aircraft (SA) because of its resemblance to modern transport aircraft, is launched vertically by means of a rocket engines, and after completion of the flight program it undergoes a controlled landing. The SA is designed for 100 missions each lasting 7-30 days, with a crew of 4-7 and maximum payload of 29.5 tons. The MTKK crew will be differentiated according to functional duties into three distinct categories: pilots, specialists in orbital operations, payload specialists. It is planned that women will also participate as specialists in the last two categories (according to data as of 1 Jan 1980, 62 people, including 6 women, are being trained among the ranks of cosmonauts for flights aboard MTKK).

The distinctive feature of the Spacelab program is that it is international. The Spacelab laboratory is being established by member nations of the European Space Agency (ESA) with the expert and consultant participation of NASA (United States) specialists. The statute of the program is defined by intergovernment agreement between the United States and ESA nations, which provide for joint collaboration up to 1988. By special agreement among ESA nations, the tentative cost of the program has been determined (500 million dollars at 1975 prices), as well as distribution of financing: 53% of the expenses to be covered by FRG, 18% by Italy, 10% by France, 6% by England, 4% by Belgium, 3% by Spain, 2% by the Netherlands, 2% by Canada, 1.5% by Denmark, 1% by Switzerland and 1% by Sweden and Ireland. Australia, India, Japan and several other countries will also participate in conducting the experiments. At the present time ESA nations are delivering to NASA the equipment for a Spacelab prototype, to prepare it for the first Spacelab 1 flight scheduled, according to the latest information, for the second quarter of 1982.

Spacelab is a multipurpose space laboratory, which consists of standardized units equipped with life support and servicing equipment. It is designed to implement basic and applied research in weightlessness with the participation of man, both in the customary habitat with the earth's atmospheric parameters (sealed module) and in open space (open platforms). The laboratory is put into near-earth orbit in the payload compartment of the SA, remaining there throughout the orbital flight (Figure 3). Spacelab supplements the functional capabilities of the space shuttle MTKK, and it can be considered as an orbital station that can function in orbit for up to 30 days (in the future, there are plans to extend this period to 90 days). By virtue of the fact that an SA is the carrier of the Spacelab, the laboratory itself and virtually all of its equipment can be reused many times. Research and maintenance of experimental equipment in the laboratory will be conducted in shifts by a separate group of payload specialists consisting of up to four people.

One of the research centers of the German Scientific Research Institute of Aviation and Cosmonautics (FRG) is being converted into the West European Center for Manned Space Flights in order to train ESA cosmonauts. There, the Spacelab crews will undergo preflight training [5].

At the first phase of operation of the space shuttle and Spacelab, the biomedical research will be limited by the short duration of the flights, no more than 10 days. It is planned, first of all, to conduct studies with the participation of man of such problems as motion sickness, decalcification processes in the body, reduction of blood erythrocyte mass, adaptation of the circulatory system to weightlessness, biorhythmology, changes in perception of time and position in space. The effects of psychological stress on vascular reactions in weightlessness and of various forms of cosmic radiation will be studied in experiments on animals (rodents and primates).

The medical studies will be conducted with due consideration of public health interests. For example, there are plans for an experiment having the following main objectives: study of processes of erythrocyte sticking

and determination of maximum size of a clot of adherent erythrocytes; determination of the most significant parameters affecting clot size and kinetics of its formation; study of viscosity of blood with clot formation; determination of poss.bility of using the effects of adherent erythrocytes and change in blood viscosity for diagnostic tests.

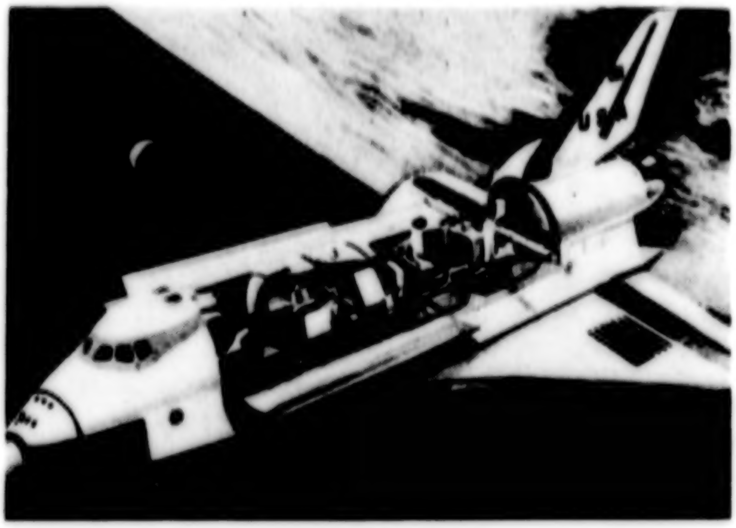

Figure 3. Space aircraft (SA) with Spacelab aboard in orbital flight (SA is shown with open doors of payload compartment, in which are contained the sealed module and open platforms of Spacelab)

There are plans to examine blood specimens from health individuals, as well as patients with hypertension, diabetes, myocardial infraction and some forms of cancer. This experiment is being prepared by a team of scientists from Australia headed by Dr Dintenfass.

Among the biomedical studies presently being prepared in the United States and ESA nations for the first flights of Spacelab, we should mention the biotechnological experiments, the joint NASA and ESA program for the study of vestibular function of man, as well as experiments on primates.

As we know, much attention has been attracted in recent times to electrostatic methods of separating biological materials in weightlessness. These methods are quite effective for the preparation of ultrapure vaccines, cell preparations, synthetic hormones and other drugs.

The National Health Institute of the United States, together with NASA, is exploring the possible use of the above products, need for them by medical institutions of the country, as well as questions of further refinement of methods of producing them in space on the basis of technology tested aboard the Skylab orbital station. These studies will be continued in the flights of the space shuttle and Spacelab orbital laboratory. During the first flights it is planned to conduct several such experiments. One of them, "Purification of hormones by electric fields in weightlessness," is being prepared by a team of scientists headed by Dr Bier and another, "Electrophoresis of human pancreatic cells," by a team of researchers headed by Dr Van Oss [6].

One can obtain biological materials in weightlessness that have materials that would be difficult or even impossible to obtain on earth (for example, biological substitutes for human tissues). Preparations are in progress at the Battel' [?] Scientific Research Institute for an experiment dealing with treatment of collagen aboard the space shutttle [7].

The treated collagen can be used to create human artificial organs, for example, blood vessels or cornea, to replace or restore natural organs. However, the soluble collagen obtained from animal tissues and treated in earth's gravity cannot be used for these purposes, since it is not a homogeneous substance. When collagen is treated in weightlessness, one can obtain a substance that is homogeneous in structure and chemical properties. This experiment is scheduled for 1981. At the present time, preparations are underway to develop equipment for automatic treatment of collagens.

A modified version of the "sled" stand, on which studies will be made of man's adaptation to weightlessness, will be installed aboard Spacelab for its first flight to conduct vestibular studies [8].

In its original version, this stand consists of a swivel chair secured on two tracks along the lateral walls within the airtight module of Spacelab. A cosmonaut seated in this chair can be submitted to linear accelerations of up to 0.2 G, generated by means of a drive that moves the chair on the tracks. Some vestibulosomatic reactions to linear accelerations in weightlessness are measured by means of sensors attached to the body. One of the objectives of these studies is to determine the correlation between the space form of motion sickness and effect of linear accelerations.

Originally, it was planned to secure the guide rails for this stand on the racks for experimental equipment situated along the lateral walls of the pressurized Spacelab module. Since the crew must have access to the equipment, the tracks had to be installed during the orbital flight. This required additional time for the studies. In addition, there was the fear that vibrations arising when the stand is in operation could have an adverse effect on the results of other studies. For this reason, it was decided to place the guide rails on the floor of the pressurized module, which makes it possible to install them before launching the

stations. The cosmonauts would be submitted to accelerations only when seated in the chair (facing the direction of movement or laterally to it) and supine (with the feet forward). ESA member nations agreed to allocate an additional $1.6 million for the vestibular research project and about $300,000 for other expenses. The existing plans provide for only one-time use of the stand as part of the Spacelab equipment; however, the number of such flights could be increased if warranted by the results of the studies.

Refinement of space engineering expands the possibilities for conducting biological experiments during manned flights, and this in turn stimulates development of new experimental research projects with animals. An international team of 34 scientists headed by Prof Burgeat has been formed at the Paris Scientific Research Center of Aerospace Medicine, for the purpose of preparing for experiments with two primates aboard the Spacelab orbital laboratory within the framework of ESA in 1984 [9]. This group includes scientists from Great Britain, Belgium, Denmark, Italy, France and Sweden. The experiments have to be planned in collaboration with the French National Space Study Center.

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